THE BRITISH ASSOCIATION AT BELFAST

THE Belfast meeting of the British Association was concluded as we went to press last week. The weather during the meeting was not all that might have been desired, but both the local committee and the visitors have reason to be thankful that the deluge which flooded Belfast a few days before the opening meeting did not occur a few days later.

The flags of the presidents were in imminent danger of destruction on account of this flood. They had been placed on a table in the Grosvenor Hall ready to be hung up for the opening address, and were saved only by the timely action of the Rev. Mr. Kerr, who divesting himself of some of his clothing, waded in to their rescue. The water afterwards rose to a height of several feet in the Hall, an occurrence never before experienced there.

With the exception of the garden party given by the local executive committee in the Botanic Gardens Park, when the rain came punctually at the hour named on the cards and departed with the guests, all the other outdoor functions went off with nothing more than a sprinkle or two.

The garden parties of the Earl and Countess of Shaftesbury and of Lord and Lady O'Neill at their picturesque residences were favoured with dry but cool afternoons, as was also that of Mr. and Mrs. J. Brown. This last included a visit to the linen factory of Mr. G. Herbert Brown, and an inspection of Mr. Brown's physical laboratory and of various applications of electric power to domestic appliances, among which an electrically driven lawn mower and the ice-making, knife-cleaning and meat-chopping machines in the kitchen offices seemed to attract most attention. The excursions arranged for Saturday were well attended, as also were those planned by the Belfast Naturalists' Field Club for the Thursday after the meeting.

General and warm approval has been expressed regarding the arrangements made by the local officials for the reception and comfort of the members, and although these were smaller in number than on the last occasion, this was not due to any falling off in those visiting Belfast, but rather to the apathy of local people, judging by the smaller number of associates' and ladies' tickets issued, as shown by the following table :—

	1874.	1902.
Old Life Members	162	243
New ,,	13	21
Old Annual Members	232	314
New ,,	85	84
Associates	817	647
Ladies	630	305
Foreign Members	12	6
	1951	1620

It has been questioned whether this falling off, especially in the number of ladies' tickets, may not be ascribed in a considerable degree to the educational methods of Ireland and their effect on the tastes of those brought up under their influence within the last thirty years.

The educational note struck in the admirable Presidential Address of Prof. Dewar seemed to ring through the entire proceedings, and not only in the new Section devoted to the subject, but in joint discussions, and notably in the excellent address of Prof. Perry in Section G, do we find this question prominent. New opinions seem to be growing, and among these are the ideas that the English public-school system must be relegated to the limbo of inefficiency and that the technical school of the kind made in Germany is all very well over there, but almost useless here.

From a scientific point of view, the meeting was without doubt an admirable one. Many important papers were brought before the sections.

At the concluding meeting of the Association, the following votes of thanks were unanimously adopted :—(1) To the Lord Mayor and Corporation for their reception of the Association; to the President and Council of the Queen's College, the Presbyterian College, the Methodist College and the Elmwood Presbyterian Church for the use of rooms; and to the Harbour Commissioners for their reception. (2) To the local secretaries—Mr. John Brown, Mr. Ferguson and Prof. Fitzgerald—Dr. Kyle Knox (the local treasurer) and the local committee for the excellent arrangements made for the reception of the Association in Belfast. (3) To the noblemen, gentlemen and public bodies who have entertained the Association; to the firms who have opened their works; to the citizens who have hospitably entertained members; to the gentlemen who have contributed to the success of the excursions; to the committees of clubs, libraries and other institutions who have opened their premises to the members of the Association; to the Belfast Tramway Company; and to the Belfast Press, for their admirable reports of the proceedings.

A noteworthy event of the meeting was the speech given by Prof. C. S. Minot, President of the American Association, in which he invited members of the British Association to attend the meeting to be held early next January at Washington. Prof. Minot said he had been directed by the council of his Association to express the hope that as many members as possible of the British Association would attend the Washington meeting. A vote had been passed to the effect that all members of the British Association would be received upon presenting themselves at the meetings in America as members of the American Association without further requirement. In future, as has already been announced in these columns, the annual meetings of the American Association will begin on the first Monday after Christmas and extend throughout the week. The scientific societies affiliated with the Association have agreed to this arrangement, and the universities have consented to the establishment of this "Convocation Week," in which the meetings of scientific societies are to be held. It is expected that the first meeting to be held next January under this rule will be the most important scientific gathering ever held in America. In the course of his remarks, Prof. Minot said :—

It was the duty, he believed, which they should all perform to attend these gatherings and take part in international intercourse. Many Americans had come to the British Association, and they had always been treated with the greatest hospitality. They arrived strangers and went away friends; they brought expectations, and took back realisations and a grateful memory. He asked for one moment in which to remind them of a new historic condition never existing in the world before. It was the first time that two great nations existed with a common speech, a common past, a common history; would they not therefore so work together that they might build up a common future? And for the scientific man this duty came first. Each nation was governed, not by the Government, but by the men of learning and above all by the universities. Nowhere, he believed, in the Anglo-Saxon world had science yet taken its place in the universities. Nowhere in the Anglo-Saxon world had the full value of scientific knowledge throughout the whole range of life, from the university down to every practical affair—nowhere, he said, had the full power of the world of science been established.

Prof. Dewar, in replying on behalf of the Association, said :—

They were all delighted to hear the kind invitation which had been extended to the members of the Association by their brother workers on the other side of the Atlantic. The great blunder we in the United Kingdom were perpetrating for many years past was in remaining ignorant of what was being done on the other side of the Atlantic. He had again and again said to manufacturers and those interested in industrial progress that if they would subsidise their chief officials by a donation which would enable them to spend their short holiday by going to see what

could be seen during a three weeks' residence in the United States, to note how they economise time there, how a person could be transferred from place to place, the freedom with which one is allowed to see the great internal organisation—if they did that they would be repaid one-hundredfold. He did not know of anything that had occurred to himself personally which had affected him so much as a short visit which he had the honour of paying to America. Both in the universities and in applied industries it was a revelation to him, and he was sure it would be a personal gratification to every member of that Association, and an entirely new revelation to them, if they took advantage of the invitation offered. He hoped some of the officials of the British Association would be present on the great occasion in Washington.

In bringing the meeting to a close, Prof. Dewar referred to the work of Joseph Black, Thomas Andrews, James Thomson, Lord Kelvin and Prof. Tait, who were connected with Belfast and had given it a leading place in scientific history.

SECTION D.

ZOOLOGY.

OPENING ADDRESS BY PROF. G. B. HOWES, D.SC., LL.D., F.R.S., PRESIDENT OF THE SECTION.

The Morphological Method and Progress.

IT is now twenty-eight years since this Association last assembled in Belfast, and to those present who can recall the meeting the proceedings of Section D will be best remembered for the delivery of an address by Huxley "On the Hypothesis that Animals are Automata, and its History," one of the finest philosophic products of his mind. At that date the zoological world was about to embark on a period of marked activity. Fired by the influence of the "Origin of Species," which had survived abuse and was taking immediate effect, the zoological mind, accepting the doctrine of evolution, had become eager to determine the lines of descent of animal forms. Marine observatories were in their infancy; the *Challenger* was still at sea; the study of comparative embryology was but then becoming a science; and when, reflecting on this, we briefly survey the present field, we can but stand astonished at the enormity of the task which has been achieved.

Development has proceeded on every hand. The leavening influence, spreading with sure effect, has in due course extended to the Antipodes and the East, in each of which portions of the globe there has now arisen a band of earnest workers pledged to the investigation of their indigenous fauna, with which they are proceeding with might and main. Of the Japanese, let it be said that not only have they filled in gaps in our growing knowledge, for which they alone have the materials at hand, but that, with an acumen deserving the highest praise, they have put us right on first principles. I refer to the fact that they have shown, with respect to the embryonic membranes of the common chick, that we in the West, with our historic associations, our methods and our skill, contenting ourselves with an ever-recurring restriction to the germinal area, have, by an error of orientation, missed an all-important septum, displaced under an inequality of growth.

Those of us who have lived and worked throughout this memorable period have had a unique experience, for never has there been progress so rapid, accumulation of observations so extensive and exact. Of the 386,000 living animal species, to compute the estimate low, every one available has been lain under hand, with the result that our annual literary output now amounts to close upon 10,000 contributions, the description of new genera and subgenera, say 1700. More than one-half of this vast series refers to the Insecta alone; but notwithstanding this, the records of facts of structure and development, with which most of us are concerned, now amount to a formidable mass, calculated to awe the unlettered looker-on, to overwhelm the earnest devotee, unless by specialising he can secure relief. As an example of what may occur, it may be remarked that a recent exploration of the great African lakes has resulted in the discovery of over 130 new species.

As to the nature of this unprecedented progress, it will suffice to consider the Earthworms. In 1874 few were known to us. An advance in our knowledge, which had then commenced, had made known but few more which seemed likely to yield result. Darwin's book upon them had not appeared. Some were exotic, it is true, but no one suspected that a group so restricted in their habits could reveal aught beyond a dull monotony of form and structure. Never was surmise more wide of the mark, for the combined investigations of a score of earnest workers in all parts of the world have in the interval recorded some 700 odd species of about 140 genera. Mainly exotic, they exhibit among themselves a structural variation of the widest possible range. Not only do we recognise littoral and branchiate forms, but others achætous and leech-like in habit, to the extent of the discovery of a morphological overlap with the leeches, under which we are now compelled to remove them from their old association with the flat worms, and to unite them with the earthworms. And we even find these animals, as represented by the Acanthodrilidæ, coming prominently into considerations which involve the theory of a former Antarctic continent, one of the most revolutionary zoo-geographical topics of our time.

This case of the earthworm may be taken as typical of the rest, since for each and every class and order of animal forms, the progress of the period through which we have passed since last we assembled here has produced revolutionary results. Our knowledge of facts has become materially enhanced; our classifications, at best but the working expression of our ideas, have been to a large extent replaced in clearer, more comprehensive schemes; and we are to-day enabled to deduce, with an accuracy proportionate to our increased knowledge of fact, the nature of the interrelationships of the living forms which with ourselves inhabit the earth.

Satisfactory as is this result, it must be clearly borne in mind that its realisation could not have come about but for a knowledge of the animals of the past; and turning now to palæontology, it may be said that at the time of our last meeting in this city the scientific world was just becoming entranced by the promise of unexpected results in the exploration of the American Tertiary beds, then being first opened up. The Rocky Mountain district was the area under investigation, and with this, as with the progress in our knowledge of recent forms, no one living was prepared for the discoveries which shortly came to pass. To consider a concrete case, we may premise that study of the placental mammals had justified the conclusion that their ancestors must have had equal and pentadactyle limbs, a complete ulna and fibula, a complete clavicle, and a skull with forty-four teeth; must have realised, that is, the predominant term of the living Insectivora as generally understood. Who among the zoologists of our time does not recall with enthusiasm the revelation which arose from the discovery, during these early days, in the Eocene of Central North America, of the genera at first described as Eo- and Helohyus? The evidence of the existence, in the locality named, of these forty-four toothed peccaries, as they were held to be, rendered clearer the records of the later Tertiary deposits of the old world, which were those of hogs, and, in correlation with the facts then known, suggested that the Rocky Mountain area was the home of the ancestral porcine stock, and that in Early Tertiary times their descendants must have migrated, on the one hand, across the northern belt, of which the Aleutian Islands now mark the course, into the old world, to beget, by complication of their teeth, the pigs and hogs; and on the other into Central South America, to give rise, by numerical reduction of teeth and toes, to the peccaries, still extant.

Migration in opposite directions with diversity of modification was the refrain of this remarkable find, far-reaching in its morphological and zoo-geographical effects. Nor can we allude with less fervour to the still more striking case of the horses, which proved not merely a similar, though perhaps a later, migration, but a parallelism of modification in both the old and new worlds, culminating in the latter in extinction, whereby it became necessary, on the advent of civilised man, to carry back the old-world horse to its ancestral American home. No wonder that this should have provoked our Huxley to the remark that in it we have the "demonstrative evidence of the occurrence of evolution," and that the facts of palæontology came to be regarded as certainly not second to those of the fascinating but seductive department of embryology, at the time making giant strides.

I have endeavoured thus to picture that state of zoological science at the time of our last meeting here; and I wish now to confine myself to some of the broader results since achieved on the morphological side. But let us first digress, in order to be clear as to the meaning of this phrase.

We do not expect the public to be accurate in their usage of scientific terms; but it is to me an astounding fact that among trained scientific experts, devotees to branches of science other than our own, there exists a gross misunderstanding as to the

limitations of our departments. I quote from an official report in alluding to "comparative anatomists, or biologists, as they call themselves," and I but cite the words of an eminent scientific friend, in referring to biology and botany as coequal. In endeavouring to get rid of this prevailing error, let it be once more said that the term "biology" was introduced at the beginning of the nineteenth century by Treviranus and Lamarck, and that in its usage it has come to signify two totally distinct things as employed by our continental contemporaries and ourselves. By "Biologie" they understand the study of the organism in relation to its environment. We, following Huxley, include in our term biology the study of all phenomena manifested by living matter; botany and zoology; and by morphology we zoologists mean the study of structure in all its forms, of anatomy, histology and development, with palæontology—of all, that is, which can be preferably studied in the dead state, as distinct from physiology, the study of the living in action. Comparative morphology, the study of likeness and unlikeness, is the basis of our working classifications, and it is to the consideration of the morphological method, and the more salient of its recent results, that I would now proceed, in so far as it may be said to have marked progress and given precision to our ideas within the last eight-and-twenty years. I would deal in the main with facts, with theories only where self-evident, ignoring that type of generalisation to which the exclusive study of embryology has lent itself, which characterises, but does not grace, a vast portion of our recent zoological literature.

To the earnest student of zoology, intent on current advance, the mental image of the interrelationships of the greater groups of animal forms is ever changing, kaleidoscopically it may be, but with diminishing effect in proportion as our knowledge becomes the more precise.

Returning now to American palæontology, we may at once continue our theme. In this vast field, expedition after expedition has returned with material rich and plentiful; and while, by study of it, our knowledge of every living mammalian order, to say the least, has been extended, and in some cases revolutionised, we have come to regard the Early Tertiary period as the heyday of the mammals, in the sense that the present epoch is that of the smaller birds. No wonder then that there should have been discovered group after group which has become extinct, or evidence that in matters such as tooth-structure there is reason to believe that types identical with those of to-day have been previously evolved but to disappear. To contemplate the discovery of the Titanotheria, the Amblyopoda, the Dinocerata, with their strange diminutive brain, chief among the heavier ungulate forms, is to consider the Mammalia anew; and when it is found that among late discoveries we have (1) that of a series of Rhinoceratoidea, which though not yet known to extend so far back in time as the primitive tapirs and horses are complete as far as they go; (2) that among the Ruminants we have, in the Oreodontidæ of the American Eocene, primitive forms with a dentition of forty-four teeth, an absence of diastemata, a pentadactyle manus, a tetradactyle pes with traces of a hallux, and, as would appear from an example of Mesoreodon, a bony clavicle, such is unknown in any later ungulate, we are aroused to a pitch of eager enthusiasm as to the outcome of labours now in hand; for, as I write, there reaches me a letter to the effect that for most of the great vertebrate groups, and not the mammals alone, collections are still coming in each more wonderful than the last.

In the extension of our knowledge of the Ancyclopoda, an order of mammals named after the Ancylotherium of Pikermi and Samos, which occur in the Early Tertiary deposits of Europe, Asia, North America and abundantly in Patagonia, we have been made aware of the existence of genera whose salient structural features combine the dentition of an ungulate with the possession of pointed claws, believed to have been retractile like those of the living cats. Conversely to these unguiculate herbivores, which include genera with limbs on both the artio- and perisso-dactyle lines, there have been found, among the so-called Mesonychidæ, undoubted primitive carnivores, indications of a type of terminal phalanx seal-like and approximately non-unguiculate; from all of which it is clear that we have in the rocks the remains of forms extinct which transpose the correlations of tooth and claw deducible from the living orders alone. Further, among the primitive pentadactyle Carnivora we meet, in the genus Patriofelis, with a reduction of the lower incisors to two, and characters of the fore-limb which, with this, suggest the seals. It is, however, probable that these characters are in no way indicative of direct genetic relationship between the two, for, inasmuch as these animals were accustomed to seek their food in the water of the lake by which they dwelt, their seal-like characters may be but the expression of adaptation to a partially aquatic mode of life—of parallelism of modification with the seals and nothing more.

Early in the history of their inquiry, our American confrères recorded from the Pliocene the discovery of camel-like forms possessed of a full upper incisor dentition; for example, the genera Protolabis and Ithygrammodon; and now they have arrived at the conclusion that while the camels are of American origin, one of their most characteristic ruminants, the Prongbuck (Antilocapra), would conversely appear to be the descendant of an ancestor (Blastomeryx) who migrated from the old world.

Sufficient this concerning the work in mammalogy of the American palæontologists. While we return them our devout and learned admiration, we would point out that the brilliance of their discoveries has but beclouded the recognition of equally important investigations going on elsewhere. In Argentina there have proceeded, side by side with the North American explorations, researches into the Pleistocene or Pampa fauna, which in result are not one whit behind, as has been proved by the recognition of a whole order of primitive ungulates, the Toxodontia, by that of toothed cetaceans with elongated nasals, as in the genera Prosqualodon and Argyrocetus, and of sperm whales with functional premaxillary teeth, viz. Physodon and Hypocetus, to say nothing of giant armadillos and pigmy glyptodons.

It will be remembered by some present that, from Patagonian deposits of supposed Cretaceous age, there was exhibited at our Dover meeting the skull of a horned chelonian Meiolania, which animal, we were informed, is barely distinguishable from the species originally discovered in Cook's Island, one of the Society group, and which, being a marsh turtle highly specialised, would seem in all probability to furnish a forcible defence for the theory of the Antarctic continent. But more than this, renewed investigation of the Argentine beds by the members of the Princeton University of North America have recently resulted in collections which, we are informed, seem likely to surpass all precedent in their bearings upon our current ideas, not the least remarkable preliminary announcement being the statement that there occurs fossil a mole indistinguishable, so far as is known, from the golden mole (Chrysochloris) of South Africa.

Before I dismiss this fascinating subject, let me disarm the notion, which may have arisen, that the palæontological work of the old world is done. Far from it! Even our American cousins have to come to us for important fossil forms; as, for example, the genus Pliohyrax of Samos and the Egyptian desert, while among the rodents and smaller carnivores there are large collections in our national museum waiting to be worked over afresh.

If one part of the globe more than another is just now the centre of interest concerning its vertebrate remains, it is the Egyptian desert. Here there have recently been found the bones of a huge cetacean associated, as in South America, with those of a giant snake, one of the longest known, since it must have reached a length of thirty feet. There also occur the remains of other snakes, of chelonians of remarkable adaptive type, of crocodilians, fishes and other animals. Interest, however, is greatest concerning the Mammalia, which for novelty are quite up to the American standard, as with an upper and a lower jaw of an anomalous creature, concerning which we can only at present remark that it may be a marsupial, or more probably a carnivore, which has taken on the rodent type in a manner peculiarly its own. Important beyond this, however, are a series of Eocene forms which more than fill a long-standing gap, viz., that of the ancestors of the Elephants and Mastodons, which hitherto stopped short in the Middle Miocene of both old and new worlds. As represented by the genus Mæritherium, they have three incisors above and two below, of which the second is in each case converted into a short but massive tusk. An upper canine is present, and in both upper and lower jaws a series of six cheek-teeth, distinct and bunodont in type. In the allied Barytherium, of which a large part of the skeleton is known, the upper incisors were presumably reduced to two, the tusks enlarged, with resemblances in detail to the Dinoceratan type.

So far as these remains are known, they appear to present in their combined characters all that the most ardent evolutionist

could desire. There are with them Mastodons which simplify our knowledge of this group; and among the last discovered remains Sirenians, which, in presenting a certain similarity to the afore-named Mœritherium, strengthen the belief in the proboscidian relationships of these aquatic forms. Finally, and perhaps most noticeable of all, there is the genus Arsinoitherium, a heavy brute with an olfactory vacuity which outrivals that of Grypotherium itself, and is surmounted by a monstrous fronto-nasal horn, swollen and bifid, for which the most formidable among the Titanotheres might yearn in vain. There is an occiput to match! The suggestion that this extraordinary beast has relationships with the Rhinocerideæ is absurd, since its tooth pattern alone inverts the order of this type. That it is a proboscidian may be nearer the mark, and if so it shows once more how subtle were the mammals of the past. Great as is this result, much remains to be done or done again, if only from the fact that in seeking to determine homologies our American brethren, in the opinion of some of us, have placed too much reliance on a so-called tritubercular theory of tooth genesis, of which we cannot admit the proof. How, we would ask, is it conceivable that a transversely ridged molar of Diprotodon type can be of tritubercular origin?

Sufficient for the moment of palæontological advance, except to remark that the zoologist who neglects this branch of morphology misses the one leavening influence; neglects the court on whose ruling arguments deduced from embryological data alone must either stand or fall. We may form our own conclusions from facts of the order before us; but it is when we find their influence on the master-mind prompting to action, like that of Huxley with his mighty memoir of 1880, in which he revised our subclass terms, that we appreciate them to the full.

With this consideration we pass to the living forms, and I have only time in dealing with these to comment on advance which affects our broadest conceptions and classifications of the past.

To commence with the Mammalia, we now know that the mammary gland when first it appears is in all forms tubular, and that this type is no longer distinctive of the Monotremata alone. We know, too, that the intranarial position of the epiglottis when at rest, long known for certain forms, is a distinction of the class. It explains the presence of the velum palatinum, by its association with the glottis for the restriction of the respiratory passage, the connection being lost in man alone, under specialisation of the organ of the voice.

Similarly, the doubly ossified condition of the coracoid may now be held diagnostic, for it is known that the epicoracoidal element, originally thought to characterise the monotremes alone, is always present, and that reduction to a varying degree characterises the metacoracoid, which retires, as in man, as the so-called coracoid epiphysis.

Our conceptions of the interrelationships of the Marsupialia and Placentalia have during the period we are considering been delimited beyond expectation, by the discovery of an allantoic placenta in a polyprotodont marsupial, in place of the vitelline, present in its allies. When it is remembered that in the formation of the placenta of the rabbit and a bat there is realised a provisional vitelline stage, it is tempting to suggest that the evidence for the direct relationship of the two mammalian subclasses first named overlaps (there being a placental marsupial on the one hand, a marsupial placental on the other), much as we have come to regard Archæopteryx as an avian reptile, the Odontornithes as reptilian birds. These facts, moreover, prove that the type of placenta inherited by the Placentalia must have been discoidal, and that from that all others were derived.

Equally important concerning our knowledge of the Marsupialia is the discovery, first made clear by Prof. Symington, of this College, that Owen was correct in denying them a corpus callosum. How Owen arrived at this conclusion it is difficult to conceive; but in these later days the history of discovery is largely that of method; and it is by the employment of chrome-silver, methylene-blue, and other reagents, which in differentiating the fibre-tracts enable us to delimit their course, that this conclusion has been proved. By the corpus callosum we now understand a series of neo-pallial fibres which transect the alveus and are present only in the Placentalia.

There is no department of mammalogy in which recent work has been more luminous than this which concerns the brain; and, to mention but one result, it may be said that in the renewed study of the commissures there has been found a fibre-tract characteristic of the Diprotodontia alone, so situated as to prove that they and the Placentalia must have specialised on diverse lines from a polyprotodont stock. Interesting this, the more, since the phalangers and kangaroos are known to be polyprotodont when young. And when we add the discovery that in the detailed relationship of its commissures the brain of the Elephant Shrew, a lowly insectivore, alone among that of all Placentalia known, realises the marsupial state, as does its accessory organ of smell, we have to admit the discovery of annectant conditions just where they should occur.

The morphological method is sound!

The master hand which has given us this result has also reinvestigated the Lemurs. From an exhaustive study of the brain or its cast of all species of the order, living and extinct, there has come the proof that the distinctive characters of the lemuroid brain are intelligible only on a knowledge of the pithecoid type; that its structural simplicity in the so-called lower lemurs is due to retrogressive change, in some species proved to be ontogenetic; and that the Tarsier, recently claimed to be an insectivore, is a lemur of lemurs. It is impossible to over-estimate the importance of this conclusion, which receives confirmation in recent palæontological work; and there is demanded a reinvestigation of those early described Tertiary fossil forms placed on the Ungulo-lemuroid border line, as also a reconsideration of current views on the evolution of the primates and of man.

In dismissing the Mammalia, we recall the capture during the period we review of three new genera, a fourth, the so-called Neomylodon, having proved by its skull to be *Grypotherium Darwinii*, already known. The African Okapi, an object of sensation beyonds its deserts, has found its place at last. To have been dubbed a donkey, a zebra and a primitive hornless giraffe is distinction indeed; and we cannot refrain from contrasting the nonsensical statement that its discovery is "the most important since Archæopteryx" with the truth that it is a giraffine, horned for both sexes, annectant between two groups well known. As a discovery it does not compare with that of the Mole-marsupial, and it falls into insignificance beside that of the South American diprotodont Cœnolestes, the survivor of a family which there flourished in Middle Tertiary times.

Passing to Birds and Reptiles, it will be convenient to consider them together. A knowledge of their anatomy has extended on all hands, and in respect to nothing more instructively than their organs of respiration. Surprise must be expressed at the discovery, in the chelonian, of a mode of advancing complication of the lung suggestive of that of birds. On looking into this, I find that Huxley, who rationalised our knowledge of the avian lung and its sacs, was aware of the fact that in our common Water-tortoise (*Emys orbicularis*), the lung is sharply differentiated along the bronchial line into a postero-dorsal more cellular mass, an antero-ventral more saccular, of which the posterior vesicle, in its extension and bronchial relationships, strangely simulates the so called abdominal sac of birds. He had already instituted comparison with the Crocodiles, aud was clearly coming to the conclusion that the arrangement in the bird is but the result of extreme specialisation of a type common to all Sauropsida with a "cellular" lung. The respiratory process in the bird may be defined as transpulmonary, and it is an interesting coincidence that, as I write, there comes to hand a memoir, supporting Huxley's conclusion, and establishing the fact that there is a fundamental principle underlying the development and primary differentiation of all types of vertebrate lung.

The discovery of the Odontornithes in the American Cretaceous is so well known, that it is but necessary to remark that nine genera and some twenty species are recognised. To Archæopteryx I shall return. Before dismissing the Chelonia, however, it must be pointed out that palæontology has definitely clenched their supposed relationship to the Plesiosaurs. Of all recent palæontological collections there are none which, for care in collecting and skill in mounting, surpass the reptilian remains from the English Jurassic (Oxford Clay) now public in our national museum. The Plesiosaurs of this series must be seen to be appreciated, and nothing short of a merciful Providence can have interposed, to ensure the generic name Cryptocleidus, which one of them has received, since the hiding of the clavicle, its diagnostic character, is an accomplished fact. It is due to secondary displacement, under the approximation in the middle line of a pair of proscapular lobes, present in the Plesiosauria and Chelonia alone, and until the advent of this discovery mis-

interpreted. Taken in conjunction with other characters of little less importance, conspicuously those of the plastron and pelvis, this decides the question of affinity, and proves the Chelonia to have had a lowly ancestry, as has generally been maintained.

Recent research has fully recorded the facts of development of the rare New Zealand reptile Sphenodon, and it has more than justified the conclusion that it is the sole survivor of an originally extensive and primitive group, the Rhynchocephalia, as now understood. To confine our attention to its skeleton, as that portion of its body which can alone be compared with both the living and extinct, it may be said that positive proof has been for the first time obtained that the developing vertebral body of the terrestrial vertebrata passes through a paired cartilaginous stage, and that in its details the later development of this body is most nearly identical with that of the lower Batrachia. There has long been a consensus of opinion that the forward extension of the pterygoids to meet the vomers in the middle line, known hitherto in this animal and the crocodiles alone, is for the terrestrial Vertebrata a primitive character; and proof of this has been obtained by its presence in all the Rhynchocephalia known. The same condition has also been found to exist in the Plesiosaurs, the Ichthyosaurs, the Pterodactyles, the Dicynodontia, the Dinosaurs, and with modification in some Chelonians. It has, moreover, been found in living birds; a most welcome fact, since Archæopteryx, in the possession of a plastron, carries the avian type a stage lower than the Dinosaurs. It is pertinent here to remark that, inasmuch as in those Dinosaurs (*e.g.* Compsognathus) in which the characters of the hind limbs are most nearly avian, the pelvis, in respect to its pubis, is at the antipodes of that of all known birds, and the fore-limb is shortened in excess of that of Archæopteryx itself, the long supposed dinosaurian ancestry for birds must be held in abeyance.

Passing through the Rhynchocephalia to the Batrachia, we have to countenance progress most definite in its results. The skull, the limbs and their girdles are chiefly concerned, and this in a very remarkable way.

In the year 1881 there was made known by Prof. Froriep, of Tübingen, the discovery that the hypoglossus nerve of the embryo mammal is possessed of dorsal ganglionated roots. Again and again have I heard Huxley insist on the fact that the ventral roots of this nerve are serial with the spinal set, but never did he suspect the rest. It is, however, a most intensely interesting fact that, whereas by a Huxleian triumph the vertebral theory of the skull was overthrown, in these later Huxleian days the proof of the incorporation of a portion of the vertebral region of the trunk into the mammalian occiput should have marked the succeeding epoch in advance. The existence of twelve pairs of cranial nerves which all the Amniota possess involves them in this change; and the fact that in all Batrachia there are but ten, enables us to draw a hard-and-fast line between batrachian and amniote series.

It may be urged, as an objection, that since we have long been familiar with a fusion of vertebræ and skull in various piscine forms, the force of this distinction is weakened. But this cannot be; since, in respect to the investing sheaths and processes of development which lie at the root of the genesis of the vertebral skeleton, the fishes stand distinct from the Batrachia and Amniota, which are agreed. So forcible is this consideration that it behoves us to express it in words, and I have elsewhere proposed to discriminate between the series of terrestrial Vertebrata as *archae-* and *syn-craniate*.

Similarly there is no proof that any batrachian, living or extinct (and in this I include the Stegocephala as a whole) possesses a costal sternum. So far as their development is known, the cartilages in these animals called "sternal" are either coracoidal or *sui generis*. The costal sternum, like the syncraniate skull, is distinctive of the Amniota alone. Had the Stegocephala possessed it even in cartilage, there is reason to think it might have been preserved, as it has been in the colossal Mososaur Tylosaurus of the American Cretaceous. When to this it is added that whereas, in the presence of a costal sternum, the mechanism of inflation of the lung involves the body-wall, in its absence it mainly involves the mouth (as in all fishes and batrachians), the hard and sharp line between the Batrachia and Amniota may be expressed by the formula that the former are *archaecraniate* and *stomatophysous*, the latter *syncraniate* and *somatophysous*.

There are allied topics which might be considered did our time permit; but one certain outcome of this is that there is an end to the notion of a batrachian ancestry for the Mammalia. And when, on this basis, we sum up the characters demanded of the stock from which the Mammalia have been derived, we find them to be precisely those occurring outside the Mammalia in the Anomodont Reptiles alone. Beyond the sternum and skull, the chief characters are the possession of short and equal pentadactyle limbs, with never more than three phalanges to a digit, a complete fibula and clavicle, a doubly ossified coracoid, a heterodont dentition—a combination which, wholly or in part, we now associate with the Permian genera Procolophon, Pariasaurus, and others which might be named, the discovery of which constitutes one of the morphological triumphs of our time.

Beyond this, it may be added, concerning the Batrachia, that among living pedate forms the Anura have alone retained the pentadactyle state and the complete maxillo-jugal arch, and that the Eastern Tylototriton, in the possession of the latter, becomes the least modified urodele extant. These facts lead to the extraordinary conclusion that the living Urodela, while of general lowly organisation, are one and all aberrant; and it is not the least important sequel to this that, despite their total loss of limbs, the Apoda, in the retention of the dermal armour and other features which might be stated, are the most primitive Batrachia that exist.

The batrachian phalangeal formula 22343 was until quite recently a difficulty in the determination of the precise zoological position of the class; but it has now been overcome, by the discovery of a Keraterpeton in the Irish Carboniferous having three phalanges on the second digit of both fore- and hind-limbs, and by that in the Permian of Saxony of a most remarkable creature, Sclerocephalus, which, if rightly referred to the Stegocephala, had a head encased, as its name implies, in an armature like that of a fish, and the phalangeal formula of a reptile, 23454.

Passing from the Batrachia to the Fishes, we have still to admit a gap, since an interminable discussion on fingers and fins has not narrowed it in the least. In compensation for this, however, we have to record within the fish series itself progress greater, perhaps, than with the higher groups. Certainly is this the case if, as to bulk, the literature in systematics and palæontology be alone taken into account.

Of the Dipnoi our knowledge is fast becoming complete. We know that Lepidosiren forms a burrow; and, in consideration of a former monstrous proposal to regard this animal, with its fifty-six pairs of ribs, and Protopterus, with its thirty to thirty-five, as varieties of a species, it is the more interesting to find that the Congo has lately yielded a Protopterus (*P. Dolloi*) with the lepidosiren rib formula, viz., fifty-four pairs.

As a foremost result of American palæontological research we have to record the occurrence, in the Devonian of Ohio, of a series of colossal fishes known as the Arthrodira, the supposed dipnoan affinities of which are still a matter of doubt.

We have evidence that the osseous skeleton in a plate-like form first appeared as a protection for the eye of a primitive shark. And coming to recent forms having special bearings on the teachings of the rocks, we have to acknowledge the capture in the Japanese seas of a couple of ancient sharks, of which one (Cladoselachus), since observed to have a distribution extending to the far North, is a survivor from Devonian times; the other (Mitsukurina) a genus whose grotesqueness leaves no doubt of its identity with the Cretaceous lamnoid Scapanorhynchus. In the elucidation of the Sturiones and the determination of their affinities with the ancient Palæoniscidæ a master stroke has been achieved. In the Old Red genus Palæospondylus we have become familiar with an unmistakable marsipobranch, possessing, as do certain living fishes, a notochord, annulated, but not vertebrated in the strict sense of the term. The climax in Ichthyopalæontology, however, has been reached in the discovery of Silurian forms, which, there is every reason to believe, explain in an unexpected way the hitherto anomalous Pteras- and Cephalaspidians, by involving them in a community of ancestry with the primitive Elasmobranchs. The genera Thelodus, Drepanaspis, Ateleaspis and Lanarkia chief among these annectant and ancestral forms, are among the most remarkable vertebrate fossils known.

Passing to the Recent Fishes alone, the discovery which must take precedence is that of the mode of origin of the skeletogenous tissue of their vertebral column. The fishes, unlike all the higher Vertebrata, have, when young, a notochord invested in

a double sheath, there being an inner chordal sheath, an outer cuticular, which latter is alone present in all the higher groups. The skeletogenous cells, by whose activity the cartilaginous vertebral skeleton is formed, arise outside these sheaths; but whereas, when proliferating, they in one series remain outside, they in the other, by the rupture of the cuticular sheath, invade the chordal. This distinction enables us to discriminate between a *Chordal series*, which embraces the Chimæroids, Elasmobranchs and Dipnoi, and a *Perichordal*, consisting of the Teleosts, Ganoids and Cyclostomes.

In consideration of the enormity of the structural gap between the cyclostomes and the higher Vertebrata this is an extraordinary result. For be it remembered that, in addition to their well-known characters, the lampreys and hags (1) in the total absence of paired fins; (2) in the presence of branchiæ, ordinarily seven in number, fourteen in *Bdellostoma polytrema*, numerically variable in individuals of certain species between six and fourteen, and doubtfully asserted in the young of one to be originally thirty-five; and (3) in the carrying up of their oral hypopophysis by the nasal organ, whereby it perforates the cranium from above, as contrasted with all the higher Vertebrata, in which, carried in with the mouth-sac, it perforates it from beneath, exhibit morphological characters of an extraordinary kind. And if we are to express these characters in terms, we may distinguish the Cyclostomes as *apterygial* and *epicraniate*, the higher Vertebrata as *hypocraniate*.[1] But this notwithstanding, the aforementioned subdivision of the Pisces into two series, which would associate the teleosts and ganoids with the cyclostomes, as distinct from the rest, receives support from recent study of the head-kidney by a Japanese, who seeks to show that the organ so called in the Elasmobranchs is of a late-formed type peculiar to itself; and it is also in agreement with one set of conclusions previously deduced from the study of the reproductive organs.

To deal further with the fishes is impossible in this Address, except to remark that recent discovery in the Gambia that the young of the Teleostean genera Heterotis and Gymnarchus bear filamentous external gills, renders significant beyond expectation the alleged presence of these among the loaches, and shows that adaptive organs of this type are valueless as criteria of affinity.

In palæontology, as in recent anatomy, our records of detail have increased beyond precedent, often but to show how deficient in knowledge we are, how contradictory are our theories and facts.

In dismissing the fishes, I wish to comment upon our accepted terms of orientation. To speak of the median fins as dorsal, caudal and anal, of the pelvic as ventral, and of the pectoral in its varying degrees of forward translocation as abdominal or thoracic, though a convention of the past, is to-day inaccurate and absurd. I question if the time has not come at which the terms thoracic (pulmocardiac) and abdominal are intolerable, as expressing either the subdivisions of the body-cavity or anything else, outside the Mammalia, which alone possess a diaphragm. Even in the birds, to grant the utmost, the subdivision of the cœlom, if accurately described, must be into pulmonary, hyper-pulmonary and cardio-abdominal chambers; while with the reptiles the modes of subdivision are so complex that a special terminology is necessary for each of the several types extant.

In the fishes, where the pericardium is alone shut off, the retention of the mammalian terms but hampers progress. This was indeed felt by Duméril, when in 1865 he attempted a revisionary scheme. Since, however, one less fantastic than his seems desirable, I would propose that for the future the "anal" fin be termed *ventral*, the "ventral" *pelvic*; and that for the several positions of the pelvic, that immediately in front of the vent, primitive and embryonic (which is the position for the Elasmobranchs, Sturiones, Lower Siluroids and all the higher Vertebrata), be termed *proctal*, the so-called "abdominal" *pro-proctal*, the so-called "thoracic" *jugular* (in that it denotes association with the area of the "collar-bone"), and the so-called "jugular" *mental*. The necessity for this becomes the more desirable, now that it is known that a group of Cretaceous fishes (the Ctenothrissidæ), hitherto regarded as Berycoids, are in reality of clupeoid affinity, despite the fact that at this early geologic period they had translocated their pelvic fin into the jugular ("thoracic") position.

The sum of our knowledge acquired during the last twenty-eight years proves to us that, among the bony fishes, the structural combination which would give us a premaxillo-maxillary gape dentigerous throughout, a proctal pelvic fin, a heart with conal valves, would be the lowest and most primitive. Inasmuch as this character of the heart, so far as at present known, exists only among the Clupesoces (pikes and herrings and their immediate allies), these must be regarded as lowly forms; wherefore it follows that the possession of but a single dorsal fin is not, as might appear, a necessary index of a highly modified state.

Before I dismiss the vertebrates, a word or two upon a recent result of morphological inquiry which concerns them as a whole. I refer to the development of the skull. Up to 1878 it was everywhere thought and taught that the cartilaginous skull was a compound of paired elements, known as the trabeculæ cranii and parachordals, and that the former contributed the cranial wall. Huxley in 1874, from the study of the cranial nerves of fishes, had reiterated the suggestion he made in 1864, when dealing with the skull alone, that the trabeculæ might be a pair of præ-oral visceral arches, serial with those which support the mouth and carry the gills. The next step lay with the Sturgeon, in which in 1878 it was found that the cranial wall is originally distinct. And later, when the facts were more fully studied in sharks, batrachians, reptiles and birds, it became evident that the trabeculæ, though ultimately associated with the cranial wall, take no share in its formation, and that when first they appear they are disposed at right angles to the parachordals and the axis, serially with the visceral arches behind. Huxley was right; and although this consideration by no means exhausts the category of independent cartilages now known to contribute to the formation of the skull, it proves that the cartilaginous cranium, like the bony one, which in the higher vertebrate forms replaces it, is in its essence compound.

I now pass to the Invertebrata. Of the Oligochæta and Leeches I have spoken, and we may next consider the Arthropods. Of the Insecta, our knowledge has gained precision, by the conclusion that the primitive number of their Malpighian tubes is six, and by the study of development of these in the American cockroach Doryphora, which has rendered it probable they may be modified nephridia, carried in as are those of some oligochætes with the proctodeal invagination. An apparent cervical placenta has been discovered in the orthopteran Hemimerus, which would seem to suggest homology with the so-called "trophic vesicle" of the Peripatoids, as exemplified by *P. Novae-Britannica*. In this same orthopteran there have been recognised, in secondary proximity to the "lingua," reduced maxillulæ, which, fully developed and interposed between the mandible and first maxilla, in Japyx, Machilis, Forficula and the Ephemera larva, give us a fifth constituent for the insectan head. And when it is found that all the abdominal segments of the common cockroach, when young, are said to bear appendages, of which the cerci are the hindermost, we have a series of facts which revolutionise our ideas. Little less striking is the discovery that in the caterpillar of the bombycine genera Lagoa and Chrysopyga seven pairs of pro-legs occur.

The fuller study of the apertures of the tracheate body has resulted in the discovery that the Chilopoda are more nearly related to the Hexapoda than to the Diplopods; wherefore it is proposed to reclassify the Tracheata, in accordance with the position of the genital orifice, into Pro- and Opistho-gonata. In a word, the "Myriapoda," if a natural group, are diphyletic.

Our knowledge of the Peripatoids (*Arthropoda malacopoda*) has increased in all that concerns distribution and structure. They are now known, for example, from Africa, the West Indies, Australia and New Zealand, and for examples from the two latter localities and Tasmania the generic name Ooperipatus has but lately been proposed, to include three species, characterised by the possession of an ovipositor, of which two have been observed to lay eggs.

Work upon the Crustacea in our own land, notorious for the tendencies of some of its devotees in their stickling for priority, has within the last twelve years advanced beyond all expectation. Much of our literature has been systematised, and an enormous increase in our knowledge of new forms has to be admitted, thanks to memoirs such as those of the "Investigator,"

[1] It is an interesting circumstance, if their "ciliated sac" is rightly homologised, that Amphioxus and the Tunicata present a corresponding dissimilarity, allowance being made for the fact that in Botryllus, Goodsiria and Polycarpa the sac overlies the ganglion. It is pertinent here to recall the ammocœte-like condition of the "endostyle" in *Oikopleura flabellum*.

"Naples Zoological Station," and others which might be named; while in the discovery and successful monographing, in the intervals of six years' labour at other groups, of a new family of minute Copepods (the Choniostomatidæ), parasitic on the Malacostraca, embracing forty-three species, difficult to find, we have an almost unique achievement. The hand which gave us this has also provided a report which embraces the description of a nauplius of exceptional type, which, by a process of reasoning by elimination, masterly in its method, has been "run to ground" as in every degree of probability the larva of Darwin's apodal barnacle *Protolepas bivincta*, of which only the original specimen is known.

There is but one other crustacean record equal in rank with this, viz., the discovery of the genus Anaspides. Originally obtained from a fresh-water pool on Mount Wellington, Tasmania, at 4000 feet, it has since been found in two other localities. It is unique among all living forms, in combining within itself characters of at least three distinct suborders of "prawns," for with a schizopod body it combines the double epipodial lamellæ of an amphipod, the head of a decapod (pedunculated eyes and antennulary statocysts) apart from characters peculiarly its own. There is reason to believe that the nearest living ally to this remarkable creature is a small eyeless species (*Bathynella natana*) obtained from a Bohemian well; and if its presumed relationships to the Palæozoic "pod-shrimps" be correct, this heterogeneous assemblage may perhaps be the representatives of a group of primitive Malacostraca, through which, by structural divergence, the establishment of the higher crustacean suborders may have come about.

It is pertinent to this to note that work upon cave-dwelling and terrestrial forms, upon "well-shrimps" and the like, has produced important results. And interesting indeed is the recent discovery of three species, living at 800-900 feet above sea-level, in Gippsland, one an amphipod, two of them isopods, which, though surface-dwellers, are all blind. While they prove to be species of genera normally eyed, they in their characters agree with well-known American forms; and the bleaching of their bodies and atrophy of their eyes proclaim them the descendants of cave-dwelling or subterranean ancestors, among whom the atrophy took place.

Huxley in 1880 rationalised our treatment of the higher Crustacea, by devising a classification by gills, expressive of the relationships of these to the limb-bases, interarticular membranes and body-wall. Hardly had his influence taken effect when, by work extending over the years 1886 to 1893, in the study of Penæus, the Phyllopods, Ostracods and other forms, evidence had been accumulating to show that the crustacean appendage, even to the mandible itself, has primarily a basal constituent (protopodite) of three segments; that the branchiæ one and all are originally appendicular in origin; and that the numerical reduction of the basal (protopoditic) segments to two, with the assumption of a non-appendicular relationship by the gills, is due to coalescence of parts, with or without suppression. The evidence for this epoch-making conclusion, which simplifies our conceptions and brings contradictory data into line, is as irresistible as it is important, and there has been nothing finer in the whole history of crustacean morphology. With it, the attempt to explain the supposed anomalous characters of the antennule by appeal to embryology goes to the wall; and, taking a deep breath, we view the Crustacea in a new light.

There remains for brief consideration one carcinological discovery second to none which bears on the significance of larval forms. It is that of the Trilobite *Triarthrus Becki*, obtained in abundance from the Lower Silurian near New York, with all its limbs preserved. In the simplicity of its segmentation and the biramous condition of its limbs it is primitive to a degree. Chief among its characters are the total absence of jaws in the strict sense of the term, and the fact that of its three anterior pairs of appendages the third is certainly and the second is apparently biramous, the first uniramous and antenniform. In this we have a combination of characters known only in the nauplius larva among all living crustacean forms; and the conclusion that the adult trilobite, like that of the Euphausiaceæ, Sergestidæ, Penæidæ, the Ostracods and Cirripedes of to-day, was derived by direct expansion of the nauplius larva can hardly be doubted. Much yet remains to be done with the study of the Triarthrus limbs; and the suggestion of a foliaceous condition by those of the pygidium, which are youngest, is a remarkable fact, the meaning of which the future must decide. We should expect the condition to be a provisional one, since while we admit the primitive nature of the phyllopods as an Order, we cannot regard the foliation of their appendages as anything but a specialisation. Be this as it may, the structural community between the nauplius larva and the trilobite is now proved; and when we add that in the yolk-bearing higher Crustacean types (*e.g.* Astacus) a perceptible halt in the development may be observed at the three-limb-bearing stage; that in Mysis the vitelline membrane is shed but to make way for a nauplius cuticle; and that the median nauplius eye has long been found sessile on the adult brain of representative members of the higher crustacean groups, up to the lobster itself, our belief in the ancestral significance of the nauplius larval form is established beyond doubt.

The thought of the nauplius suggests other larval forms. The gastrula is no longer accepted without reserve; the claims of the blastula, planula, parenchymella, not to say the plakula, have all to be borne in mind. It is of the Trochophore, however, as familiar as the nauplius, that I would rather speak, as influenced by recent research. It is supposed to be primitive for the molluscs and chætopod worms at least; and various attempts have been made to bolster it up, and to show that if we allow for adaptive change, its characters, well known, are constant within the limits of its simpler forms.

It is now more than forty years ago that the late Lacaze-Duthiers described for Dentalium a larval stage, characterised by the possession of recurrently ciliated zones, which by reduction, with union and translocation forwards, give rise to the trochal lobe. It is now known that in the American pelecypod *Yoldia limatula* a similar stage is found, in which a "test," of five rows of ciliated cells, is present; and of the young of *Dondersia banyulensis* the like is true. But whereas in the Yoldia the ciliated sac is ultimately shed, in the Myzomenian the escape of the embryo is accompanied by rupture which liberates the anterior series of ciliated zones in a manner strongly suggestive of forward concentration, leaving the posterior circlet with its cilia attached.

This "test" has also been seen in two species of Nucula, and pending fuller inquiry into the Myzomenian and a reinvestigation of Dentalium, I would suggest that this recurrently ciliated sac is representative of a larval stage antecedent to the trochophore, for which the term *protrochal* may suffice. This term has indeed been already applied to a larva of certain Polychæta, which might well represent a modification of that for which I am arguing; and quite recently it appears to have been observed near Ceylon for a species of the genus Marphysa.

The discovery of this larva in Dondersia was accompanied by that of a later-formed series of dorsal spicular plates, which for once and for all, in realising a chitonid stage, demolish the heresy of the "Solenogastres," mischievous as suggesting an affinity with the worms. Like that of the supposed cephalopod affinities of the so-called "Pteropods," it must be ignored as an error of the past.

Returning to the protrochal stage, whatever the future may reveal concerning it, by bringing together the Lamellibranchiata, Scaphopoda and Polyplacophora, it associates in one natural series all the bilaterally symmetrical Mollusca except the cephalopods. In doing this, it deals the death-blow to the supposed Rhipidoglossan affinity of the Lamellibranchiata; and in support of this conclusion I would point out that the recently discovered eyes of the mytilids are in the position of those of the embryo Chiton, and that just as Dentalium, in the formation of its mantle, passes through a lamellibranchiate stage, so are there lamellibranchs in number in which a tubular investment is found.

This protrochal larva has an important part to play. It may very possibly explain phenomena such as the compound nature of the trochal lobe of the limpet, the presence of a post-oral ciliated band in the larva of the ship-worm, and of a præ-anal one in that of various molluscan forms. In view of it, we must hesitate before we fully accept the belief in the ancestral significance of the trochophore. And it is certain that an idea, at one time entertained, that the Rotifer (Trochosphæra) which so closely resembles it as to bear its name is its persistent representative is wrong, since this is now known to be but the female of a species having a very ordinary male.

Through the Rhipidoglossa we pass to the Gastropods which are one and all asymmetrical, for even Fissurella, Patella and Doris, when young, develop a spiral shell; while Huxley in 1877 had observed that the shell of Aplysia, in its asymmetry, betrays its spiral source.

The notion, which until recently prevailed, that among these gastropods the non-twisted or so-called euthyneurous condition of the visceral nerve-cords, as exemplified by the Opisthobranchs, is a direct derivative of that of the Chitons has been proved to be erroneous, since the nerves in Actæon and Chilina, like those of the prosobranchs, are twisted or streptoneurous. And as to the torsion of the gastropod body, recent research, in which one of my pupils has played a part, involving the discovery of paired reno-pericardial apertures in Haliotis, Patella and Trochus, has resulted in proof that the dextral torsion which leads to the monotocardiac condition does not uniformly affect all organs lying primitively to the left of the rectum, as we have been taught; since, concerning the renal organs, it is the *primitively* (pretorsional) left one which remains as the functional kidney, its ostium as the genital aperture. Nor is the primitively right kidney necessarily lost, for while its ostium remains as the renal orifice, its body, by modification and reduction, may become an appendage of the functional kidney, the so-called nephridial gland. And we now know there are cases of sinistral torsion of the visceral hump, in which the order of suppression of the organs is not reversed, the arrangement being one of adaptation of a dextral organisation to a sinistral shell.

Though thus specialised and asymmetrical as a group, the gastropods are yet plastic to an unexpected degree. Madagascar has yielded a Physa (*P. lamellata*) with a neomorphic gill, a character shared by species of Planorbis (*P. corneus* and *P. marginatus*), and an Ancylus in which the lung-sac is suppressed; while St. Thomas's Island has given us a snail (*Thyrophorella Thomensis*), the peristome of whose shell is produced into a protective lid.

In palæontology, history records the fact that in 1864 Huxley observed that the genus Belemnites appears to have borne but six free arms; a startling discovery which lay dormant till the present year. And the recent study of the fauna of the great African lakes, in bringing to light the existence of a halolimnic molluscan series in Lake Tanganyika, has opened up new possibilities concerning the palæontological resources of enormous aqueous deposits, recently discovered in the interior, and has entirely changed our geological conceptions of the nature of Equatorial Africa.

Time prevents my dealing with other groups, and it must suffice to say that with those I have not considered substantial work has been done. From what has been said, it is natural to expect that in some direction or another so vast an accumulation of facts must have extended the Darwinian teaching; and it is now quite clear that this has been the case with the two post-Darwinian principles known as "Substitution" and Isomorphism or "Convergence."

The former may be exemplified by nothing better than the case of the Rays and Skates, in which, under the usurpation of the propelling function of the tail by the expanded pectoral fins, the tail, free to modify, becomes in one species a lengthy whip-lash, in another a vestigial stump, in others, by the development of powerful spines, a formidable organ of defence. In both the Rays and certain other fishes subject to the working of this law, modification goes further still, in the appearance of electric organs in remotely related genera and species, by specialisation of the muscular system of the trunk or tail, or, as in the case of Malapterurus, of "tegumental glands." In this we have a difficulty admitted by Darwin himself, which now becomes clear and intelligible, since there is nothing new. There has simply come about the conversion, in one case of the energy of muscular contraction, in the other of glandular secretion, into that of electrical discharge, with accompanying structural change. The blind locust (*Pachyramina fuscifer*) of the New Zealand Limestone caves presents an allied case, since here, under the reduction of the eye, the antennæ, elongated to a remarkable degree, have become the more efficiently tactile; and it is an interesting question whether this principle may not explain the attenuation of the limbs in the recently discovered American Proteoid (*Typhlomolga Rathburni*) of the Texan subterranean waters.

And as to isomorphism, by which we mean the assumption of a similar structural state by members of diverse or independent groups, I would recall the case of the Eocene Creodont Patriofelis and the Seals, and that of the Myriapods to which I have already alluded, and would cite that of the Dinosaurs and Birds, heterodox though it may appear, for reasons I have given.

As our knowledge increases, there is every reason to believe that, in the non-appreciation of these principles in the past, not a few of our classifications are wrong. We have even had our bogies, as, for example, the so-called Physemaria, which deceived the very elect; and before I close I wish to deal briefly with a question of serious doubt, which these considerations suggest.

It is that of the position in the zoological series of the Limuloids, popularly termed the King Crabs. These creatures, best known from the opposite shores of the Northern Pacific, but found in the oriental seas as well as far south as Torres Strait, have been since 1829 the subject of a difference of opinion as to their zoological position and affinities. Within the last twenty years there have been three determined advances upon them, and of these the third and most recent may be first discussed. It has for its object the attempt to prove that they are intimately associated with the cephalaspidian and other shield-bearing fishes of the Devonian and Silurian epochs, and that through them they are ancestral to the Vertebrata. The latest phase of this idea is based on the supposed existence in a Cephalaspis of a series of twenty-five to thirty lateral appendages of arthropod type. When, however, it is found that the would-be limbs are but the edges of body-scutes misinterpreted, suspicion is aroused; and when, working back from this, an earlier attempt reveals the fact that the author, compelled to find trabeculæ, in order to force a presupposed comparison between the architecture of the Cephalaspidian head-shield and the Limulus' prosomal hood, resorts to a comparison between the structure of the former in general and that of the cornu of the latter, with details which on the piscine side are not to date, the argument must be condemned. It violates the first principles of comparative morphology, and is revolting to common sense; and as to the fishes concerned, we know that they have nothing whatever to do with the Limuloids, for we have already seen that, with their allies the Pteraspidiæ, they are a lateral branch of the ancestral piscine stem.

The second advance upon the king crabs has very much in common with the first. It has engrossed the attention of an eminent physiologist for the last six or seven years, and by him it was in detail set before Section I at our meeting of 1896. Suffice it to say that it specially aims at establishing a structural community between the king crabs and certain vertebrates, favourable to the conviction that the Vertebrata have had an arthropod ancestry. When we critically survey the appalling accumulation of words begotten of this task, it is sufficient to consider its opening and closing phases. At the outset, under the conclusion that the vertebrate nervous axis is the metamorphosed alimentary canal of the arthropod ancestor, the necessity for finding a digestive gland is mainly met by homologising the so-called liver of the arthropod with the cellular arachnoid of the larval lamprey, in violation of the first principles of comparative histology! At the close we find ingenious attempts to homologise nerve tracts and commissures related to the organs of sense, such as are invariably present wherever such organs occur. Sufficient this to show that the comparison, in respect to its leading features, is in the opening case strained to an unnatural degree, in the closing case no comparison at all. Finding, as we do, that the rest of the work is on a par with this, we are compelled to reject the main conclusion as unnatural and unsound; and when we seek the explanation of this remarkable course of action, we are forced to believe that it lies in the failure to understand the nature of the morphological method. For the proper pursuit of comparative morphology, it is not sufficient that any two organisms chosen here and there should be compared, with total disregard of even elementary principles. Comparison should be first close and with nearly related forms, passing later into larger groups, with the progressive elimination of those characters which are found to be least constant. And necessary is it, above all things, that in instituting comparison it should be first ascertained what it is that constitutes a crustacean a crustacean, a marsipobranch a cyclostome, and so on for the rest. We have tried to accept this theory, fascinated both by the arguments employed and by the idea itself, which for ingenuity it would be difficult to beat, but we cannot; and we dismiss it as misleading, as a fallacy, begotten of a misconception of the nature of the morphological method of research. It is of the order of events which led Owen to compare a cephalopod and a vertebrate, led Lacaze-Duthiers to regard the Tunicata and Lamellibranchs as allied; and with these and other heresies it must be denounced.

Passing to the third advance, extending over the last twenty years, it may be said to consist in the revival of a theory of 1829, which boldly asserts that Limulus is an Arachnid. In the development of the defence there have been two weak points but lately strengthened, viz., the insufficient consideration of the palæontological side of the question and of the presence of tracheæ among the Arachnida. Under the former there was, until recently, assumed the absence of the first pair of appendages in the Eurypterida; but it may be said that they have since been observed in *Eurypterus Fischeri* of the Russian Silurian, and *E. scoticus* from the Pentland Hills, in both of which they consist of small chelate appendages flexed and limuloid in detail, somewhat reduced perhaps, and enclosed by the bases of the succeeding limbs, which become apposed as the anterior end is reached. Since by this discovery the Limuloids, Eurypterids and Scorpionids are brought into a numerical harmony of limb-bearing parts, we may at once proceed to other points at issue. So far as the broader structural plan of Limulus and the Scorpion are concerned, all will agree to a general community, except for the organs of respiration; but concerning the cœlom, the mobile spermatozoa and the more detailed features under which Limulus is held to differ from the Crustacea and to resemble the Arachnida, I would remark that while motile spermatozoa are characteristic of the Cirripedes, the rest of the argument is weakened, by the probability that the "arachnidan" characters which remain may well have been possessed by the crustacean ancestors, and that Limulus, though specialised, being still an ancient form, might have retained them. The difficulty does not seem to me to lie in this, or with the excretory organs, if we are justified in accepting the aforementioned argument that the so-called Malpighian tubes may be inturned nephridia, ectodermal in origin, and in knowledge of the existence of endodermal excretory diverticula in the Amphipods. These facts would seem to suggest that as our experience widens, differences of this kind will disappear.

As to the tracheal system, now adequately recognised by the upholders of the arachnid theory, the presumed origin of tracheæ from lung-books, the probability that the ram's-horn organ of the Chernetidæ may be tracheal, the presence of tracheæ in a simple form in the Acari, and, by way of an anomaly, in a highly organised form on the tibiæ of the walking legs of the harvestmen (Phalangidæ), are all features to be borne in mind. While I am prepared to admit that this wide structural range and varied distribution of the tracheæ lessens their importance as a criterion of affinity, I cannot accept as conclusive the evidence for the assumed homology between lung-books and gills. And here it may be remarked that a series of paired abdominal vesicles, recently found in the remarkable arachnid Kœnenia, invaginate as a rule but in one example everted, seized upon in defence of this homology, have not been so regarded by those most competent to judge.

There remains the entosternite, an organ upon which much emphasis has been placed. Not only does a similar organ exist, apart from an endophragmal system, in Apus, Cyclops, some Ostracods and Decapods, but, regarding the question of its histology, it may be pointed out that, from all that is at present known, the structural differences between these several entosternites do not exceed those between the cartilages of the Sepia body. And when it is found that the figures and descriptions of the entosternite of Mygale ("Mygale sp.," "Mygalomorphous Spider," *auct.*) have been thrice presented upside down! the reliability of this portion of the argument is lessened, to say the least.

Recent observation has sought to clench the homology of the four posterior pairs of limbs of the King Crab and Scorpion, by appeal to a furrow on the fourth segment in the former, believed to denote an original division into two; but I hesitate to accept this until myological proof has been sought.

Returning, amidst so much that is problematic, to the sure ground of palæontology, I wish to point out that when all is considered in favour of the arachnid theory there still remains another way of interpreting the facts.

In both Limulus and the Scorpion the first six of the eighteen segments are well known to be fused into a prosoma bearing the limbs, but while in the Scorpion the remaining twelve are free, in Limulus they are united into a compact opisthosomal mass. In dealing with the living arthropods, there is no character determinative of position in the scale of this or that series more trustworthy than the antero-posterior fusion of segments. It has been called the process of "cephalisation," and the degree of its backward extension furnishes the most trustworthy standard of highness or lowness in a given assemblage of forms. In passing from the lower to the higher Crustacea, we find this fusion increasing as we ascend: and it therefore becomes necessary to compare the Scorpion with the other Arachnida, Limulus with the Eurypterida, in order the better to determine the position of each in its respective series, by the application of this rule.

As to the number of segments present, variation is a matter of small concern, in consideration of the mode of origin of segmentation and the wide numerical range—from seven in the Ostracods to more than sixty in Apus—the segments of the crustacean class present.

On the arachnidan side, in the Solifugæ but the third and fourth segments are fused; the remaining four of the prosomal series with the ten which remain are free. In Kœnenia four of the prosomal segments alone unite; the fifth and sixth with the rest are free. And when we pass to the Limuloids and the descending series of their allies, we find it distinctive of the Eurypterida that all the opisthosomal segments are free. If we can trust these comparisons, we must conclude that the Eurypterida of the past, in respect to their segmentation, simplify the Limuloid type, on lines similar to that on which the Solifugæ and Kœnenia simplify the Higher Arachnid and Scorpionid type, and that therefore, if the degree of antero-posterior fusion of segments has the significance attached to it, Limulus and Scorpio must each stand at the summit of its respective series. If this be admitted, it has next to be asked if, in comparing them, we may not be comparing culminating types, which might well be isomorphic.

The scorpions are known fossil by two genera, Palæophonus and Proscorpius, from the Silurian of Gotland and Lanarkshire, the Pentland Hills and New York State; while recent research, in the discovery of the genus Strabops, has traced the Eurypterida back to the Cambrian, leaving the scorpions far behind. One striking feature of the limbs of the Palæozoic Eurypterids is their constantly recurring shortness and uniformly segmented character, long known in Slimonia, and less conspicuously in Pterygotus itself, retained with development of spines in three of five known appendages of the recently described eurypterid giant Stylonurus. The minimum length yet observed for these appendages is that of the Silurian species *Eurypterus Fischeri*, discovered by Holm in Russia in 1898. This creature is one of the few eurypterids in which all the appendages are preserved, and it is the more strange therefore that the advocates of the arachnid theory should ignore it in their most recent account. Allowing for the specialisation of its sixth prosomal appendage for swimming, the fifth is but little elongated, the second, third and fourth are each in total length less, by far, than the transverse diameter of the prosoma, and uniformly segmented, giving the appearance of short antennæ. They seem to be seven-jointed, and are just such appendages as exist in the simpler crustacean and tracheate forms; and in the fact that their structural simplicity is correlated with the independence of the whole series of opisthosomal segments they lend support to the argument for isomorphism.

With this conclusion, we turn once more to the Scorpions, if perchance something akin to it may not be in them forthcoming. The Silurian genus Palæophonus, especially as represented by the Gotland specimen, reveals the one character desired. Its body does not appear to be in any marked degree simpler than that of the living forms; but on turning to its limbs, we find the four posterior pairs, in length much shorter than those of any living species, all but uniformly segmented. In this they approximate towards the condition of the limbs of the Eurypterida just dismissed, and their condition is such that had they been found fossil in the isolated state they would have been described as the limbs of a Myriapod, and not of a scorpion at all. Indeed, their very details are what is required, since in the possession of a single terminal claw they differ from the limbs of the recent scorpions as do those of the Chilopoda from the hexapods.

With this the scorpionid type is carried back, with a structural simplification indicative of a parallelism with the other arthropod groups; and while the facts do not prove the total independence of the scorpionid and limuloid series, they bring the latter into closer harmony with the Eurypterida of the past. They prove that the Silurian Scorpions simplify the existing Scorpionid type, on precisely the lines on which the Eurypterida simplify the Limuloid; and they do so in a manner which suggests that a distinction between the *Crustacea vera* and the *Crustacea gigantostraca* (to include the Eurypterida and

Xiphosura) is the nearest expression of the truth. It becomes thereby the more regrettable that in a recent revision of the taxonomy of the Limuloids the generic name Carcinoscorpius should have found a place.

I foresee the objection that the antenniform condition of the shorter limbs may be secondary and due to change. There is no proof of this. Against it, it may be said that the number of the segments is normal, and that where nature effects such a change, elongation is with the multi-articulate state the only process known; as, for example, with the second leg of the Phrynidæ, the so called second pareiopod of the Polycarpidea and the last abdominal appendage of Apseudes.

That advances such as we have now considered should lead to new departures is a necessity of the case; and it but remains for me to remind you that within the last decade statistical and experimental methods have very properly come more prominently into vogue, in the desire to solve the problems of variation and heredity. Of the statistical method, by no means new, I have but time to recall to you the Presidential Address of 1898 by my friend and predecessor in this chair, himself a pioneer; and of the experimental method I can but cite an example, and that a most satisfactory one, justifying our confidence and support. It concerns the late Prof. Milne-Edwards, who in 1864 described, from the Paris Museum, the head of a rock lobster (*Palinurus penicillatus*), having on the left side an antenniform eye-stalk. With the perspicuity distinctive of his race, he argued in favour of the "fundamental similarity of parts susceptible to revert to their opposite states." The matter remained at this till, on the removal of the ophthalmite of certain Crustacea, it was found that in regeneration it assumes a uniramous multiarticulate form; and it is an interesting circumstance that in the common crayfish the biramous condition normal to the antennule may occur. An example this of a fact which no other method could explain.

When all is said and done, however, it is to the morphological method that I would appeal as most trustworthy and sound. And when we find (1) that in certain compound Tunicates the atrial wall, in the egg development delimited by a pair of ectoblastic invaginations, in the bud development may be formed from the parental endodermic branchial sac; (2) that regenerated organs are by no means derivative of the blastemata whence they originally arose; (3) that in the development of a familiar star-fish the inner cells of the earliest segmentation stages, by intercalation among the outer, contribute half the fully-formed blastula; (4) that there are Diptera in existence in which, while it is well-nigh impossible to discriminate between the adult forms, there is reason to believe the pupa cases are markedly and constantly distinct; it becomes only too evident that the later embryonic and adult states are those most trustworthy for all purposes of comparison, and that it is by these that our animals can best be known and judged. Caution is, however, necessary with senility and age, since certain skulls have been found to assume at this period characters and proportions strikingly abnormal, and by virtue of the most important discovery, which we owe to the Japanese, that in certain Holothurians the calcareous skeletal deposits may so change with age as to render specific diagnoses based on their presumed immutability invalid. Advance, real and progressive, is in no department of zoological inquiry better marked than comparative morphology, and it is for the preeminence of this that I would plead. Educationally, it affords a mental discipline second to none.

We live by ideas, we advance by a knowledge of facts, content to discover the meaning of phenomena, since the nature of things will be for ever beyond our grasp.

And now my task is done, except that I feel that we must not leave this place without a word of sympathy and respect for the memory of one of its sons, an earnest devotee to our cause. William Thompson, born in Belfast, 1806, became in due time known as "the father of Irish natural history." By his writings on the Irish fauna, and his numerous additions to its lists, he secured for himself a lasting fame. In his desire to benefit others, he early associated himself with the work of the Natural History Society, which still flourishes in this city. He was President of this Section in 1843, and died in London in 1852, while in the service of our Association, in his forty-seventh year, beloved by all who knew him. His memory still survives; and if, as a result of this meeting, we can inspire in the members of the Natural History and Philosophic Society of this city, as it is now termed, and of its Naturalists' Field Club an enthusiasm equal to his, we shall not have assembled in vain.

SECTION G.

ENGINEERING.

OPENING ADDRESS BY PROF. JOHN PERRY, M.E., D.Sc., LL.D., F.R.S., PRESIDENT OF THE SECTION.

THIS Section has had sixty-six Presidents, all different types of engineer. As each has had perfect freedom in choosing the subject for his Address, and each has known of the rule[1] that Presidential Addresses are not subject to debate afterwards, and as, being an engineer, he has always been a man of originality, of course he has always chosen a subject outside his own work. An engineer knows that the great inventions, the great suggestions of change in any profession, come from outsiders. Lawyers seem like fish out of water when trying to act as law-makers. The radical change that some of us hope to see before we die in the construction of locomotives will certainly not come from a locomotive superintendent who cannot imagine a locomotive which is not somehow a lineal descendant of the Rocket.

Hence it is that in almost every case the President of this Section has devoted a small or large part of his Address to the subject of the education of engineers. I grant that every President has devoted his life to the education of one engineer—himself—and it is characteristic of engineers that their professional education proceeds throughout the whole of their lives. Perhaps of no other man can this be said so completely. To utilise the forces of Nature, to combat Nature, to comprehend Nature as a child comprehends its mother, this is the pleasure and the pain of the engineer.[2] A mere scientific man analyses Nature; takes a phenomenon, dissects it into its simpler elements, and investigates these elements separately in his laboratory. The engineer cannot do this. He must take Nature as she is, in all her exasperating complexity. He must understand one of Nature's problems as a whole. He must have all the knowledge of the scientific man, and ever so much more. He uses the methods of the scientific man, and adds to them methods of his own. The name given to these scientific methods of his own or their results is sometimes "common-sense," sometimes "character," or "individuality," or "faculty," or "business ability," or "instinct." They come to him through a very wide experience of engineering processes, of acquaintance with things and men. No school or college can do more than prepare a young man for this higher engineering education which lasts through life. Without it a man follows only rule of thumb, like a sheep following the bell-wether, or else he lets his inventiveness or love of theory act the tyrant.

When a man has become a great engineer and he is asked how it happened, what his education has been, how young engineers ought to be trained, as a rule it is a question that he is least able to answer, and yet it is a question that he is most ready to answer. He sees that he benefited greatly by overcoming certain difficulties in his life; and forgetting that every boy will have difficulties enough of his own, forgetting that although a few difficulties may be good for discipline many difficulties may be overwhelming, forgetting also that he himself is a very exceptional man, he insists upon it that those difficulties which were personal to himself ought to be thrown in the path of every boy. It often happens that he is a man who is accustomed to think that early education can only be given through ancient classics. He forgets the dulness, the weariness of his schooldays. Whatever pleasure he had in youth—pleasure mainly due to the fact that the average Anglo-Saxon boy invents infinite ways of escaping school drudgery—he somehow connects with the fact that he had to learn classics. Being an exceptional boy, he was not altogether stupefied and did not altogether lose his natural inclination to know something of his own language; and he is in the habit of thinking that he learnt English through Latin, and that ancient classics are the best mediums through which an English boy can study anything.[3]

1 The Committees of Sections G and L have arranged a discussion on "The Education of Engineers," this Address being regarded as opening the discussion. Thus the rule is not in force this year.

2 Of all the unskilled labour of the present day, surely that of the modern poet is the most grotesque. How much more powerful and powerless man seems to us now; how much more wonderful is the universe than it was to the ancients! Yet our too learned poets prefer to copy and recopy the sentiments of the ancients rather than try to see the romance which fills the lives of engineers and scientific men with joy.

3 The very people who talk so much of learning English through Latin neglect in the most curious ways those Platt-Deutsch languages, Dutch and Scandinavian, a knowledge of which is ten times more valuable in the study of what is becoming the speech of the world. And how they do scorn Lowland Scotch!

The cleverest men of our time have been brought up on the classics, and so the engineer who cannot even quote correctly a tag from the Latin grammar, who never knew anything of classical literature, insists upon it that a classical education is essential for all men. He forgets the weary hours he spent getting off Euclid and the relief it was to escape from the class-room not quite stupefied, and he advocates the study of pure mathemathics and abstract dynamics as absolutely necessary for the training of the mind of every young engineer. I have known the ordinary abominable system of mathematical study to be advocated by engineers who, because they had passed through it themselves, had really got to loathe all kinds of mathematics higher than that of the grocer or housekeeper. They said that mathematics had trained their minds, but they did not need it in their profession. There is no profession which so much requires a man to have the mathematical tool always ready for use on all sorts of problems, the mathematical habit of thought the one most exercised by him; and yet these men insist upon it that they can get all their calculations done for them by mathematicians paid so much a week. If they really thought about what they were saying, it would be an expression of the greatest contempt for all engineering computation and knowledge. He was pitchforked into works with no knowledge of mathematics, or dynamics, or physics, or chemistry, and, worse still, ignorant of the methods of study which a study of these things would have produced; into works where there was no man whose duty it was to teach an apprentice; and because he, one in a thousand, has been successful, he assures us that this pitchforking process is absolutely necessary for every young engineer. He forgets that the average boy leaves an English school with no power to think for himself, with a hatred for books, with less than none of the knowledge which might help him to understand what he sees, and he has learnt what is called mathematics in such a fashion that he hates the sight of an algebraic expression all his life after.

I do not want to speak of boys in general. I want only to speak of the boy who may become an engineer, and before speaking of his training I want to mention his essential natural qualification—that he really wishes to become an engineer. I take it to be a rule to which there are no exceptions that no boy ought to enter a profession—or, rather, to continue in a profession—if he does not love it. We all know the young man who thinks of engineering things during office hours and never thinks of them outside office hours. We know how his fond mother talks of her son as an engineer who, with a little more family influence and personal favour, and if there was not so much competition in the profession, would do so well. It is true, family influence may perhaps get such a man a better position, but he will never be an engineer. He is not fit even to be a hewer of wood and drawer of water to engineers. Love for his profession keeps a man alive to its interests all his time, although, of course, it does not prevent his taking an interest in all sorts of other things as well; but it is only a professional problem that warms him through with enthusiasm. I think we may assume that there never yet was an engineer worth his salt who was not fond of engineering, and so I shall speak only of the education of the young man who is likely to be fond of engineering.

How are we to detect this fondness in a boy? I think that if the general education of all boys were of the rational kind which I shall presently describe, there would be no great difficulty; but as the present academic want of system is likely to continue for some time, it is well to consider things as they are. Mistakes must be made, and the parent who tries during the early years of his offspring to find out by crafty suggestion what line his son is likely to wish to follow will just as probably do evil by commission as the utterly careless parent is likely to do evil by omission. He is like the botanical enthusiast who digs up plants to see how they are getting on. But in my experience the Anglo-Saxon boy can stand a very great deal of mismanagement without permanent hurt, and it can do no kind of boy any very great harm to try him on engineering for a while. Even R. L. Stevenson, whose father seems to have been very persistent indeed in trying to make an engineer of him against his will, does not seem, to a Philistine like myself, to have been really hurt as a literary man through his attendance on Fleeming Jenkins' course at Edinburgh—on the contrary, indeed. It may be prejudice, but I have always felt that there is no great public person of whom I have ever read who would not have benefited by the early training which is suitable for an engineer.

I am glad to see that Mr. Wells, whose literary fame, great as it is, is still on the increase, distinguishes the salt of the earth or saviours of society from the degraded, useless, luxurious, pleasure-loving people doomed to the abyss by their having had the training of engineers and by their possessing the engineer's methods of thinking.

It may be that there are some boys of great genius to whom all physical science or application of science is hateful. I have been told that this is so, and if so I still think that only gross mismanagement of a youthful nature can have produced such detestation. For such curious persons, engineering experience is, of course, quite unsuitable. I call them "curious" because every child's education in very early years is one in the methods of the study of physical science; it is Nature's own method of training, which proceeds successfully until it is interfered with by ignorant teachers who check all power of observation and the natural desire of every boy to find out things for himself. If he asks a question, he is snubbed; if he observes Nature as a loving student, he is said to be lazy and a dunce, and is punished as being neglectful of school work. Unprovided with apparatus, he makes experiments in his own way, and he is said to be destructive and full of mischief. But however much we try to make the wild ass submit to bonds and the unicorn to abide by the crib, however bullied and beaten into the average schoolboy type, I cannot imagine any healthy boy suffering afterwards by part of a course of study suitable for engineers, for all such study must follow Nature's own system of observation and experiment. Well, whether or not a mistake has been made, I shall assume the boy to be likely to love engineering, and we have to consider how he ought to be prepared for his profession.

I want to say at the outset that I usually care only to speak of the average boy, the boy usually said to be stupid, ninety-five per cent. of all boys. Of the boy said to be exceptionally clever I need not speak much. Even if he is pitchforked into works immediately on leaving a bad school, it will not be long before he chooses his own course of study and follows it, whatever course may have been laid down for him by others. I recollect that when in 1863 I attended an evening class held in the Model School, Belfast, under the Science and Art Department, on Practical Geometry and Mechanical Drawing, there was a young man attending it who is now well known as the Right Honourable William J. Pirrie. He had found out for himself that he needed a certain kind of knowledge if he was to escape from mere rule-of-thumb methods in shipbuilding work; it could at that time be obtained nowhere in the North of Ireland except at that class, and of course he attended the class. For forty two years the Science and Art Department, which has recently doubled its already great efficiency, has been giving chances of this kind to every clever young man in the country, from long before any Physical Science was taught in any English public school.[1] The one essential thing for the exceptional boy is that he shall find within his reach chances to take advantage of; chances of learning; chances of practice; and, over and above all, chances of meeting great men. It takes me off my subject a little, but I should like here to illustrate this matter from my own personal experience.

I had already been an apprentice for four years at the Lagan Foundry when I entered Queen's College for a course of Civil Engineering. I suppose that there never was on this earth a college so poorly equipped for a course of engineering study. Even the lecture room—this lecture room in which you are now sitting—was borrowed from the Physics Professor. There was a narrow passage, ironically called a "Drawing Room," and this was the only space reserved for engineering in a town whose engineering work was even then very important. There were some theodolites and levels and chains for surveying, but nothing else in the way of apparatus. But there was as Professor a man of very great individuality; he acted as President of this Section twenty-eight years ago. I can hardly express my obligations to Prof. James Thomson. It was my good fortune to be a pupil both of this great man and of his younger brother, Lord Kelvin, as well as of Dr. Andrews. It is not because these three men were born in Belfast that we here call them great. It is not because Tait, late of Edinburgh, and

[1] I once stated that my workshop at Clifton College in 1871 was the first school workshop in England. I understand that this is a mistake; there had been a work hop at Rossall for some years. But I believe I am right in saying that my physical laboratory at Clifton was the first school laboratory in England. These ideas were not mine; they were those of the Headmaster, now the Bishop of Hereford.

Purser, now the President of Section A, were professors at this College that we call them great. All the scientific men of the world are agreed to call these men very great indeed. To come in contact with any of them, even for a little while, as a student, altered for ever one's attitude to Nature. It was not that they gave us information, knowledge, facts. The syllabuses of their courses of study were nothing like so perfect as that of the smallest German polytechnic. And yet if a youth with a liking for physical science had gone to a German Gymnasium to the age of nineteen, and had become a walking encyclopædia on leaving one's polytechnic at the age of twenty-four, the course of that life-study would not have done for him as much good as was done by a month's contact with one of these men. People call it "personal magnetism" and think there is something occult about it. In truth, they revealed to the student that he himself was a man, that mere learning was unimportant, that one's own observation of some common phenomenon might lead to important results unknown to the writers of books. They made one begin to think for oneself for the first time. Let me give an example of how the thing worked.

James Thomson was known to me as the son of the author of my best mathematical books, but more particularly as the man who had first used Carnot's principle in combination with the discovery of Joule, and I often wondered why Rankine and Clausius and Kelvin got all the credit of the discovery of the second law of thermodynamics. Men think of this work of his merely as having given the first explanation of regelation of ice and the motion of glaciers. He was known to me as the inventor of the Thomson Turbine and Centrifugal Pump and Jet Pump. His name was to be found here and there in all my text-books, always in connection with some thoroughly well-worked-out investigation, as it is to be found in all good text-books now; for wherever he left a subject, there that subject has remained until this day; nobody has added to it or found a mistake in it. He was to me a very famous man, and yet he treated me as a fellow-student. One of his early lectures was about flowing water, and he told us of a lot of things he had observed, which also I had observed without much thought; and he showed how these simple observations completely destroyed the value of everything printed in every text-book on the subject of water flowing over gauge-notches, even in the otherwise very perfect Rankine. I felt how stupid I had been in not having drawn these conclusions myself, but in truth till then I had never ventured for a moment to criticise anything in a book. I have been a cautious critic of all statements in text-books ever since. If any engineer wants to read what is almost the most instructive paper that has ever been written for engineers, let him refer to the latest paper written by James Thomson on this subject.[1] The reasoning there given was given to me in lectures in this very room in 1868, and had been given to students for many years previous.

Again, soon afterwards, he let me see that although I had often looked at the whirlpool in a basin of water when the central bottom hole is open, and although I had read Edgar Allen Poe's mythical description of the Maëlstrom, I had been very much too careless in my observation. Among other things, Thomson had observed that particles of sand gradually passed along the bottom towards the hole. When he found out the cause of this, it led him at once to several discoveries of great importance. Indeed, the study of this simple observation gave rise to all his work on (1) What occurs at bends of pipes and channels, and why rivers in alluvial plains bend more and more; (2) The explanation of the curious phenomena that accompany great forest fires; (3) The complete theory of the great wind circulation of the earth, published in its final form as the Bakerian Lecture of the Royal Society in 1892.

But why go on? He taught me to see that the very commonest phenomenon had still to reveal important secrets to the understanding eye and brain, and that no man is a true student unless he is a discoverer. And so it was with Kelvin and Andrews. Their names were great before the world, and yet they treated one as a fellow-student. Is any expenditure of money too large if we can obtain great men like these for our Engineering Colleges? Money is wanted for apparatus and more particularly for men, and we spend what little we have on bricks and mortar!

The memory of a man so absolutely honest as Prof. James Thomson was compels me to say here that I was in an exceptionally fit state to benefit by contact with him, for I hungered for scientific information.[1] I do not think that there was so much benefit for the average student whose early education had almost unfitted him for engineering studies. To work quantitatively with apparatus is good for all students, but it is absolutely necessary for the average student, and, as I said before, there was no apparatus. Also the average student cannot learn from lectures merely, but needs constant tutorial teaching, and the Professor had no assistant.

Anybody who wants to know what kind of engineering school there ought to be in such a college as this can see excellent specimens (sometimes several in one town) in Glasgow, Birmingham, Liverpool, London, Manchester, Leeds, Bristol, Nottingham, Edinburgh and other great cities. There the fortunate manufacturers have given many hundreds of thousands of pounds for instruction in applied science (engineering). In America the equipment of such schools is much more thorough and there are large staffs of teachers, for fortunate Americans have contributed tens of millions of pounds for this kind of assistance to the rising generation. Germany and Switzerland compete with America in such preparation for supremacy in manufacture and engineering, and nearly every country in the world is more and more recognising its importance as they see the great inventions of Englishmen like Faraday and Perkin and Hughes and Swan developed almost altogether in those countries which believe in education. Even one hundred thousand pounds would provide Queen's College, Belfast, with the equipment of an engineering school worthy of its traditions and position, and Belfast is a city in which many large business fortunes have been made.

It is interesting to note that the present arrangements of the Royal University of Ireland, with which this College is affiliated, are such that most of the successful graduates in engineering of Queen's University would now be debarred from taking the degree. Even in London University, Latin is not a compulsory subject for degrees in science; Ireland has taken a step backwards towards the Middle Ages at the very time when other countries are stepping forward.

Well-equipped schools of applied science are getting to be numerous, but I am sorry to say that only a few of the men who leave them every year are really likely to become good engineers. The most important reason for this is that the students who enter them come usually from the public schools; they cannot write English; they know nothing of English subjects; they do not care to read anything except the sporting news in the daily papers; they cannot compute; they know nothing of natural science; in fact, they are quite deficient in that kind of general education which every man ought to have.

I am not sure that such ignorant boys would not benefit more by entering works at once than by entering a great engineering school. They cannot follow the College courses of instruction at all, in spite of having passed the entrance examination by cramming. Whereas after a while they do begin to understand what goes on in a workshop; and if they have the true engineer's spirit, their workshop observation will greatly correct the faults due to stupid schoolwork.[2]

Perhaps I had better state plainly my views as to what general education is best for the average English boy. The public schools of England teach English through Latin, a survival of the time when only special boys were taught at all, and when there was only one language in which people wrote. Now the *average* boy is also taught Latin, and when he leaves school for the army or any other pursuit open

[1] Brit. Assoc. Report, 1876, pp. 243–266.

[1] Some of our most successful graduates went direct to works from the Model School, Belfast, and afterwards attended this College. No school in the British Islands could have given better the sort of general education which I recommend for all boys. English subjects were especially well taught, so that boys became fond of reading all manner of books. There were good classes in freehand and machine drawing, classes in chemistry and physics (at that time I believe that there were no such classes in any English public school), and the teaching of mathematics was good. Some of the masters started classes also under the Science and Art Department. Some of the masters had much individuality, and there was no outside examination to restrain it; there was only encouragement. Evidence has been given before a committee of the London School Board as to the excellence of the teaching at this school forty years ago. Foreign languages were not in the regular curriculum, but they could be studied by boys inclined that way; and in my opinion this is the position that all languages other than English ought to take in any British school. With such preparation a boy was eager and able to understand what went on in engineering works from his first day there.

[2] When I was young I remember that there were many agricultural colleges in Ireland; they have all but one been failures. Why? Because the entering pupils were not prepared by early education to understand the instruction; this had done as much as possible to unfit them.

to average boys he cannot write a letter, he cannot construct a grammatical sentence, he cannot describe anything he has seen. The public-school curriculum is always growing, and it is never subtracted from or rearranged. There is one subject which ordinary schoolmasters can teach well—Latin.

The other usual nine subjects have gradually been added to the curriculum for examination purposes; they are taught in water-tight compartments—or, rather, they are only crammed, and not taught at all. Our school system resembles the ordinary type of old-established works, where gradual accretion has produced a higgledy-piggledy set of shops which one looks at with stupefaction, for it is impossible to get business done in them well and promptly, and yet it seems impossible to start a reform anywhere. What is wanted is an earthquake or a fire—a good fire—to destroy the whole works and enable the business to be reconstructed on a consistent and simple plan. And for much the same reason our whole public-school system ought to be "scrapped." What we want to see is that a boy of fifteen shall be fond of reading, shall be able to compute and shall have some knowledge of natural science; or, to put it in another way, that he shall have had mental training in the study of his own language, in the experimental study of mathematics and in the methods of the student of natural science. Such a boy is fit to begin any ordinary profession, and whether he is to enter the Church, or take up medicine or surgery, or become a soldier, every boy ought to have this kind of training. When I have advocated this kind of education in the past I have usually been told that I was thinking only of boys who intend to be engineers; that it was a specialised kind of instruction. But this is very untrue. Let me quote from the recommendations of the 1902 Military Education Committee (Report, p. 5):—

"The fifth subject which may be considered as an essential part of a sound general education is experimental science; that is to say, the science of physics and chemistry treated experimentally. As a means of mental training, and also viewed as useful knowledge, this may be considered a necessary part of the intellectual equipment of every educated man, and especially so of the officer, whose profession in all its branches is daily becoming more and more dependent on science." When statements of this kind have been made by some of us in the past, nobody has paid much attention; but I beg you to observe that the headmaster of Eton and the headmaster of St. Paul's School are two of the members of the important Committee who signed this recommendation, and it is impossible to ignore it. Last year, for the first time, the President of the Royal Society made a statement of much the same kind, only stronger, in his annual address. I am glad to see that the real value of education in physical science is now appreciated; that mere knowledge of scientific facts is known to be unimportant compared with the production of certain habits of thought and action which the methods of scientific study usually produce.

As to English, the Committee say: "They have no hesitation in insisting that a knowledge of English,[1] as tested by composition, together with an acquaintance with the main facts of the history and geography of the British Empire, ought in future to hold the *first* place in the examination and to be exacted from all candidates." The italics are mine. It will be noticed that they say nothing about the practical impossibility of obtaining teachers. As to mathematics, the Committee say: "It is of almost equal importance that every officer should have a thorough grounding in the elementary part of mathematics. But they think that elementary mechanics and geometrical drawing, which under the name of practical geometry is now often used as an introduction to theoretical instruction, should be added to this part of the examination, so as to ensure that at this stage of instruction the practical application of mathematics may not be left out of sight." As Sir Hugh Evans would have said, "It is a very discretion answer—the meaning is good"; but I would that the Committee had condemned abstract mathematics for these army candidates altogether.

This report appears in good time. It would be well if Committees would sit and take evidence as to the education of men in the other professions entered by our average boys. It is likely that when an authoritative report is prepared on the want of education of clergymen, for example, exactly the same statements will be made in regard to the general education which ought to precede the technical training; but perhaps a reference may be made in the report to the importance of a study of geology and biology as well as physical science. Think of the clergyman being able to meet his scientific enemies in the gate!

Thanks mainly to the efforts of a British Association Committee, really good teaching of experimental science is now being introduced into all public schools, in spite of most persistent opposition wearing an appearance of friendliness. In consequence, too, of the appointment of a British Association Committee last year, at what might be called the psychological moment, a great reform has already begun in the teaching of mathematics.[2] Even in the regulations for the Oxford Locals for 1903, Euclid is repudiated. It seems probable that at the end of another five years no average boy of fifteen years of age will have been compelled to attempt any abstract reasoning about things of which he knows nothing; he will be versed in experimental mathematics, which he may or may not call mensuration; he will use logarithms, and mere multiplication and division will be a joy to him; he will have a working power with algebra and sines and cosines; he will be able to tackle at once any curious new problem which can be solved by squared

[1] Only one subject—Latin—is really educational in our schools. I do not mean that the average boy reads any Latin author after he leaves school, or knows any Latin at all ten years after he leaves school. I do not mean that his Latin helps him even slightly in learning any modern language, for he is always found to be ludicrously ignorant of French or German, even after an elaborate course of instruction in these languages. I do not mean that his Latin helps him in studying English, for he can hardly write a sentence without error. I do not mean that it makes him fond of literature, for of ancient literature or history he never has any knowledge except that Cæsar wrote a book for the third form, and on English literature his mind is a blank. But I do mean that as the ordinary public-school master is really able to give a boy easy mental exercises through the study of Latin, this subject is in quite a different position from that of the others. If any proof of this statement is wanted, it will be found in the published utterances of all sorts of men—military officers, business men, lawyers, men of science, and others—who, confessedly ignorant of "the tongues," get into a state of rapture over their school experiences and the efficiency of Latin as a means of education. All this comes from the fact, which schoolboys are sharp enough to observe, that English schoolmasters can teach Latin well, and they do not take much interest in teaching anything else. It is a power inherited from the Middle Ages, when there really was a simple system of education. I ask for a return to simplicity of system. English (the King's English; I exclude Johnsonese) is probably the richest, the most complex language, the one most worthy of philologic study; English literature is certainly more valuable than any ancient or modern literature of any one other country yet admiration for it among learned Englishmen is wonderfully mixed with patronage and even contempt. At present, is there one man who can teach English as Latin is taught by nearly every master of every school? Just imagine that English could be so taught by teachers capable of rising to the level of our literature!

I have often to give advice to parents. I find the average parent exceedingly ignorant of his son's character or inclinations or ability. He pays a schoolmaster handsomely for taking his son off his hands except during holidays. During the holidays, so terrible to a parent, he sees his son as little as possible. One question always asked is: Do you think it better to have "theoretical" instruction (they always call it by this absurd name) before or after an actual apprenticeship in works? Of course, such a question cannot be answered offhand. You tell the parent, to his great astonishment, that you must see the boy himself. When at length you see him, the chances are that you will find him to be what the schoolmasters are making of all our average boys. No part of his school work has been a pleasure to him, and, although he has had to work hard at his books, not one of the above three powers is his—power to use books and to write his own language; the language of his nurse, his mother, his mistress that is to be, his enemies and friends; the only language in which he thinks—power to compute and a liking for computation—power to understand a little of natural phenomena. Honestly I practically never find that such a boy has had any education at all except what he has obtained at home or from his school companions or from his sports. Even his sports are to keep him healthy of body only and not at all to cultivate his mental powers. Those old games like "Prisoners' Base," which really developed in a wonderful way not only all the muscles of the body, but also the thinking power, are scorned in the public schools. Think now how such a boy is handicapped if we pitchfork him into works where it is nobody's duty to teach him anything, or send him to college, where he cannot understand the lectures. Of course, if he is very eager to be an engineer he will, by hook or by crook, get to understand things. I have met some such men—clever, successful engineers in spite of all sorts of adverse circumstances—but the best of them are willing to admit that they are, and have always been, greatly hurt by the absence of the three powers which I have specified. And if this has been so in the past, when the scientific principles underlying engineering have been simple, how much more so is it now, when every new discovery in physics is producing new branches of engineering!

[1] This Committee recommends for the Woolwich and Sandhurst candidates a reform that has already been carried out by London University. No dead language is to be compulsory, but unfortunately some language other than English is still to be compulsory. Those boys, of whom there are so many, who dislike and cannot learn another language are still to be labelled "uneducated." Must there, then, be national defeat and captivity before our chosen race gives up its false academic gods? We think of education in the most slovenly fashion. The very men who say that *utility* is of no importance are the men who insist on the usefulness of a knowledge of French or German. They say that a man is illiterate if he knows only English, although he may be familiar with all English literature and with other literatures through translations. The man who has passed certain examinations in his youth and never cares to read anything is said to be educated. The men of the city of the Violet Crown, were they not educated? And did they know any other than their own language?

[2] Discussion last year and report of Committee, published by Macmillan.

paper; and he will have no fear of the symbols of the infinitesimal calculus. When I insist that a boy ought to be able to compute, this is the sort of computation that I mean. Five years hence it will be called "elementary mathematics." Four years ago it was an unorthodox subject called "practical mathematics," but it is establishing itself in every polytechnic and technical college and evening or day science school in the country. Several times I have been informed that on starting an evening class, when plans have been made for a possible attendance of ten or twenty students, the actual attendance has been 200 to 300. Pupils may come for one or two nights to a class on academic mathematics, but then stay away for ever; a class in practical mathematics maintains its large numbers to the end of the winter.[1]

Hitherto the average boy has been taught mathematics and mechanics as if he were going to be a Newton or a Laplace; he learnt nothing and became stupid. I am sorry to say that the teaching of mechanics and mechanical engineering through experiment is comparatively unknown. Cambridge writers and other writers of books on experimental mechanics are unfortunately ignorant of engineering. University courses on engineering—with one splendid exception, under Prof. Ewing at Cambridge—assume that undergraduates are taught their mechanics as a logical development of one or two axioms; whereas in many technical schools under the Science and Art Department, apprentices go through a wonderfully good laboratory course in mechanical engineering. We really want to give only a few fundamental ideas about momentum and the transformations of energy and the properties of materials, and to give them from so many points of view that they become part of a student's mental machinery, so that he uses them continually. Instead of giving a hundred labour-saving rules which must be forgotten, we ought to give the one or two ideas which a man's commonsense will enable him to apply to any problem whatsoever and which cannot be forgotten. A boy of good mathematical attainments may build on this experimental knowledge afterwards a superstructure more elaborate than Rankine or Kelvin or Maxwell ever dreamt of as being possible. Every boy will build some superstructure of his own.

I must not dwell any longer on the three essential parts of a good general education which lead to the three powers which all boys of fifteen ought to possess; power to use books and to enjoy reading; power to use mathematics and to enjoy its use; power to study Nature sympathetically. English Board School boys who go to evening classes in many technical schools after they become apprentices are really obtaining this kind of education. The Scotch Education Board is trying to give it to all boys in primary and secondary schools. It will, I fear, be some time before the sons of well-to-do parents in England have a chance of obtaining it.

When a boy or man of any age or any kind of experience enters an engineering college and wishes to learn the scientific principles underlying a trade or profession, how ought we to teach him? Here is the reasonable general principle which Profs. Ayrton and Armstrong and I have acted upon, and which has so far led us to much success. Whether he comes from a bad or a good school, whether he is an old or young boy or man, approach his intelligence through the knowledge and experience he already possesses. This principle involves that we shall compel the teacher to take the pupil's point of view[2] rather than the pupil the teacher's; give the student a choice of many directions in which he may study; let lectures be rather to instruct the student how to teach himself than to teach him; show the student how to learn through experiment and how to use books, and, except for suggestion and help when asked for, leave him greatly to himself. If a teacher understands the principle he will have no difficulty in carrying it out with any class of students. I myself prefer to have students of very different qualifications and experience in one class because of the education that each gives to the others. Usually, however, except in evening classes, one has a set of boys coming from much the same kind of school, and, although perhaps differing considerably as to the places they might take in an ordinary examination, really all of much the same average intelligence. Perhaps I had better describe how the principle is carried out in one case—the sons of well-to-do parents such as now leave English schools at about fifteen years of age.

It was for such boys that the courses of instruction at the Finsbury Technical College (the City and Guilds of London Institute) were arranged twenty-two years ago. It was attempted to supply that kind of training which ought already to have been given at school, together with so much technical training as might enable a boy at the end of a two years' course to enter any kind of factory where applied science was important, with an observing eye, an understanding brain and a fairly skilful hand. The system, in so far as it applies to various kinds of mechanical engineering, will be found described in one of a small collection of essays called "England's Neglect of Science," pp. 57-67.[1] I am sure that any engineer who reads that description will feel satisfied that it was the very best course imaginable for the average boy of the present time. A boy was taught how he must teach himself after he entered works. If after two or three years in the works he cared to go for a year or so to one of the greater colleges, or did not so care, it was assumed that he had had such a training as would enable him to choose the course which was really the best for him.

Old Finsbury students are to be found everywhere in important posts. The experiment has proved so successful that every London Polytechnic, every Municipal Technical School in the country has adopted the system, and in the present state of our schools I feel sure that all important colleges ought to adopt the Finsbury system. It hardly seems appropriate to apply the word "system" to what was so plastic and uncrystallised and had nothing to do with any kind of ritual.

The Professors were given a free hand at Finsbury, and there were no outside examiners. I need not dwell upon the courses in Chemistry and Physics; some critics might call the subjects *Rational* Chemistry and Applied Physics; they were as different from all other courses of study in these subjects as the courses on Rational Mathematics and Mechanics differed from all courses elsewhere. The course on Mechanics was really one on Mechanical Engineering. There were workshops in wood and iron, not to teach trades, but rather to teach boys the properties of materials. There were a steam-engine and a gas-engine, and shafting and gearing of many kinds, and dynamos which advanced students in turn were allowed to look after under competent men. There was no machine which might not be experimented with occasionally. Elementary and advanced courses of lectures were given; there was an elaborate system of tutorial classes, where numerical and squared paper exercise work was done; there were classes in experimental plane and solid geometry, including much graphical calculation; boys were taught to make drawing-office drawings in pencil only, and tracings and blue prints, such as would be respected in the workshop, and not the ordinary drawing-class drawings, which cannot be respected anywhere; but the most important part of the training was in the Laboratory, in which every student worked, making quantitative experiments. An offer of a 100-ton testing-machine for that laboratory was made, but refused; the advanced students usually had one opportunity given them of testing with a large machine, but not in their own laboratory. I consider that there is very little educational value in such a machine; the student thinks of the great machine,[2] and not of

[1] To many men it will seem absurd that a real working knowledge of what is usually called higher mathematics, accompanied by mental training, can be given to the average boy. In the same way it seemed absurd 500 years ago that power to read and write and cipher could be given to everybody. These general beliefs of ours are very wonderful.

[2] Usually it is assumed that there is only one line of study. In mathematics it is assumed that a boy has the knowledge and power and past experience and leisure of an Alexandrian philosopher. In mechanics we assume the boy to be fond of abstract reasoning, that he is a good geometrician who can do the most complex things in geometrical conics, but cannot possibly take in the simplest idea of the calculus.

[1] The ideas in this Address have been put forward many times by Prof. Ayrton and myself. See the following, among other publications:—"England's Neglect of Science" (Fisher Unwin); "Practical Mechanics," 1881 (Cassell); "Applied Mechanics," 1897 (Cassell); "The Steam Engine, &c.," 1898 (Macmillan); "The Calculus for Engineers," 1897 (Arnold); Recent Syllabuses and Examination Papers of the Science and Art Department in Subjects I., VII., V*p*, and XXII.; Summary of Lectures on Practical Mathematics (Board of Education); The Work of the City and Guilds Central Technical College (*Journal* of the Society of Arts, July 9, 1897); Inaugural Lecture at Finsbury, 1879; Address at the Coventry Technical Institute, February, 1898; "Education of an Electrical Engineer" (*Journal* of the Society of Telegraph Engineers and of Electricians, September, 1882); Presidential Address, Institution of Electrical Engineers, January, 1892; "The Best Education for an Engineer" (NATURE), October 12, 1899; Address at a Drawing-room Meeting, March, 1887.

[2] These great testing-machines, so common in the larger colleges, seem to have destroyed all idea of scientific experiment. There is so much that the engineer wants to know, and yet laboratory people are persistently and lazily repeating old work suggested and begun by engineers of sixty years ago. For example, men like Fairbairn and Robert Napier would long ago have found out the behaviour of materials under combined stresses. We do not even know the condition of strength of iron or steel in a twisted shaft which is also a beam. The theory of strength of a gun or thick tube under

the tiny specimen. Junior students loaded wires and beams, or twisted things with very visible weights, and saw exactly what was happening, or they studied vibrating bodies. Many hours were devoted to experiments on a battered, rusty old screw-jack, or some other lifting-machine, its efficiency under many kinds of load being determined, and students studied their observations using squared paper, as intently as if nobody had ever made such experiments before. There was one piece of apparatus, an old fly-wheel bought at a rag and-bone shop, to which kinetic energy was given by a falling weight, which, I remember, occupied the attention of four white-headed directors of Electric Companies in 1882 (evening students) for many weeks. A casual first measurement led on to corrections for friction and stiffness of a cord, and much else of a most interesting kind. At the end of six weeks these gentlemen had gained a most thorough computational acquaintance with every important principle of mechanics, a knowledge never to be forgotten. They had also had a revelation such as comes to the true experimenter—but that is too deep a subject.

Perhaps teachers in the greater colleges will smile in a superior way when they hear of this kind of experimental mechanics being called engineering laboratory work. True it was elementary mechanics; but is not every principle which every engineer constantly needs called a mere elementary principle of mechanics by superior persons? I find that these elementary principles are very much unknown to men who have passed through elaborate mathematical studies of mechanics. Students found out in that laboratory the worth of formulæ; they gained courage in making calculations from formulæ, for they had found out the extent of their own ignorance and knowledge.

I have never approved of elaborate steam-engines got up for students' laboratory exercise-work. A professor who had devoted much thought for a year to the construction of such a four-cylinder engine showed a friend how any one or any two or any three or all four cylinders, with or without jacketing, could be used in all sorts of ways. The friend ventured to say: "This engine will be used just once and never after." The professor was angry, but his friend proved to be right. The professor made experiments with it once himself with a few good students. Unfortunately, it was not a sufficiently elaborate investigation for publication. Afterwards he never had time personally to superintend such work; his assistants were busy at other things; his students could not be trusted with the engine by themselves, and to this day it stands in the laboratory a beautiful but useless piece of apparatus. At Finsbury there was an excellent one-cylinder engine with vaporising condenser. It drove the workshops and electric generators. On a field-day it drove an electric generator only, and perhaps thirty students made measurements. Each of them had already acted as stoker and engine-driver, as oiler and tester of the machinery, lighting fires, taking indicator diagrams, weighing coals, opening and closing cocks from seven in the morning to ten at night, so that everything was well known to him. They maintained three different steady loads for trials of three hours each. They divided into groups, one from each group ceasing to take a particular kind of observation every ten minutes and removing to another job. All watches were made to agree, and each student noted the time of each observation. These observations were:—Taking indicator diagrams, checking the speed indicator, taking temperature of feed-water, quantity of feed by meter (the meter had been carefully checked by gauge-notch, and every other instrument used by us had been tested weeks before), taking the actual horse-power passing through a dynamometer coupling on the shaft, taking boiler and valve-chest pressures and vacuum pressures on the roof and in the engine-room, weighing coals (the calorific value had already been tested), taking the horse-power given out by the dynamo, counting the electric lamps in use, and so on. Each student was well prepared beforehand. During the next week he reduced his own observations, and some of the results were gathered on one great table. One lesson that this taught could never be forgotten—how the energy of one pound of coal was disposed of. So much up the chimney or by radiation from boiler or steam-jacket and pipes; in condensation in the cylinder; to the condenser; in engine friction; in shaft friction, &c. I cannot imagine a more important lesson to a young engineer than this one taught through a common working engine. The students had the same sort of experience with a gas-engine. I need hardly say how important it was that the Professor himself should take charge of the whole work leading up to, during, and after such a field-day.

The difficulty about all laboratory exercise work worth the name is that of finding demonstrators and assistants who are wise and energetic. Through foolishness and laziness the most beautiful system becomes an unmeaning routine, and the more smoothly it works the less educational it is. In England just now the curse of all education is the small amount of money available for the wages of teachers—just enough to attract mediocre men. I have been told, and I can easily imagine, that such men have one talent over-developed, the talent for making their job softer and softer, until at length they just sit at a table, maintaining discipline merely by their presence, answering the questions of such students as are earnest enough to come and worry them. In such cases it is absolutely necessary to periodically upset their clockwork arrangements. After such an artificial earthquake one might be reminded of what occurred at the pool of Bethesda, whose waters had their healing property restored when the angel came down and troubled them. But for a permanently good arrangement there ought to be very much higher wages all round in the teaching profession.

No kind of engineering has developed so rapidly as the electrical. Why, it was at the meeting here in Belfast twenty-eight years ago (I remember, for I was a Secretary of Section A that year, and took the machine to pieces afterwards in Lord Kelvin's laboratory) that there was exhibited for the first time in these islands a small Gramme machine. This handmaid of all kinds of engineering is now so important that every young engineer may be called uneducated who has not had a training in that kind of mechanical engineering which is called electrical engineering. Prof. Ayrton's laboratory at Finsbury is the model copied by every other electrical engineering laboratory in the world. He and I had the same notions; we had both been students of Lord Kelvin; we had worked together in Japan since 1875; but whereas I was trying to make my system of teaching mechanical engineering replace an existing system, or want of system, there was no existing system for his to replace. Thus it will be found that in every electrical engineering laboratory the elementary principles are made part of a pupil's mental machinery by many quantitative experiments, and nobody suggests that it is mere elementary physics which is being taught—a suggestion often enough made about the work in my mechanical laboratory. When students know these elementary principles well, they can apply their mathematics to the subject. As they advance in knowledge they are allowed to find out by their own experiments how their simple theories must be made more complex in real machines. Their study may be very complete, but, however much mathematics and graphical calculation may come in, their designs of electrical machinery are really based upon the knowledge acquired by them in the electrical and mechanical laboratories.

The electrical engineer has an enormous advantage over other engineers; everything lends itself to exact calculation, and a completed machine or any of its parts may be submitted to the most searching electrical and magnetic tests, since these tests, unlike those applied by other engineers, do not destroy the body tested. But for this very reason, as a finished product, the electrical engineer cannot have that training in the exercise of his judgment in actual practical work after he leaves a college that some other engineers must have. In tunnelling, earthwork and building, in making railways and canals, the engineer is supremely dependent on the natural conditions provided for him, and these conditions are never twice the same. There are no simple laws known to us about the way in which sea and river currents will act upon sand and gravel, and engineers who have had to do with such problems are continually appealing to Nature, continually making observations and bringing to bear upon their work all the knowledge and habits of thought that all their past experience has given them. I do not know that there is any job which a good teacher would have greater

hydraulic pressure is no clearer now than it was fifty years ago. The engineer asks for actual information derived from actual trial, and we offer him the "cauld kail het again" stuff falsely called "theoretical," which is found in all the text-books (my own among others). These great colleges of university rank ought to recognise that it is their duty to increase knowledge through the work of their advanced students. The duty is not neglected in the electrical departments of some of the colleges. Perhaps the most instructive reference is to the work done at the Central Technical College of the City and Guilds Institute at South Kensington, as described by Prof. Ayrton in some of the papers already referred to. I cannot imagine a better development of the Finsbury idea in the work of the highest kind of Engineering College.

pleasure in undertaking than the arrangement of a laboratory in which students might study for themselves such problems as come before railway, canal, river, harbour and coast-protection engineers; there is no such laboratory in existence at the present time, and in any case it could only be of use in the way of mere suggestion to an engineer who had already a good knowledge of his profession.

It was a curious illustration of mental inertia that the usual engineering visitor, even if he was a professor of engineering, always seemed to suppose that the work done at Finsbury was the same as that done in all the great engineering colleges. As a matter of fact, no subject was taught there in the same manner as it was taught elsewhere.[1]

Most of the students were preparing for electrical or mechanical engineering, and therefore we thought it important that nearly every professor or demonstrator or teacher should be an engineer. I know of nothing worse than that an engineering student should be taught mathematics or physics or chemistry by men who are ignorant of engineering, and yet nothing is more common in colleges of applied science.[2] The usual courses are only suitable for men who are preparing to be mere mathematicians, or mere physicists, or mere chemists. Each subject is taken up in a stereotyped way, and it is thought quite natural that in one year a student shall have only a most elementary knowledge of what is to the teacher such a great subject. The young engineer never reaches the advanced parts which might be of use to him; he is not sufficiently grounded in general principles; his whole course is only a preliminary course to a more advanced one which there is no intention of allowing him to pursue, and, not being quite a fool, he soon sees how useless the thing is to him. The Professor of Chemistry ought to know that until a young engineer can calculate exactly by means of a principle, that principle is really unknown to him. For example, take the equation supposed to be known so well,

$$2H_2 + O_2 = 2H_2O.$$

It is never understood by the ordinary elementary chemical student who writes it down so readily. Every one of the six cunning ways in which that equation conveys information ought to be as familiar to the young engineer as they are, or ought to be, to the most specialised chemist. Without this he cannot compute in connection with combustion in gas and oil engines and in furnaces. But I have no time to dwell on the importance of this kind of exact knowledge in the education of an engineer.

Mathematics and physics and chemistry are usually taught in watertight compartments, as if they had no connection with one another. In an engineering college this is particularly bad. Every subject ought to be taught through illustrations from the professional work in which a student is to be engaged. An engineer has been wasting his time if he is able to answer the questions of an ordinary examination paper in chemistry or pure mathematics. The usual mathematical teacher thinks most of those very parts of mathematics which to an ordinary man who wants to *use* mathematics are quite valueless, and those parts which would be altogether useful and easy enough to understand he never reaches; and, as I have said, so it is also in chemistry. Luckily, the physics professor has usually some small knowledge of engineering; at all events he respects it. When the pure mathematician is compelled to leave the logical sequence which he loves to teach mechanics, he is apt scornfully to do what gives him least trouble; namely, to give as "mechanics" that disguised pure mathematics which forms ninety per cent. of the pretence of theory to be found in so many French and German books on machinery. As pure mathematical exercise work it is even meaner than the stupid exercises in school algebras; as pretended engineering it does much harm because a student does not find out its futility until after he has gone through it, and his enthusiasm for mathematics applied to engineering problems is permanently hurt. But how is a poor mathematical professor who dislikes engineering, feeling like Pegasus harnessed to a common waggon—how is he to distinguish good from evil? He fails to see how worthless are some of the books on "Theoretical Mechanics" written by mathematical coaches to enable students to pass examinations. An engineer teaching mathematics would avoid all futilities; he would base his reasoning on that experimental knowledge already possessed by a student; he would know that the finished engineer cannot hope to remember anything except a few general principles, but that he ought to be able to apply these, clumsily or not, to the solution of any problem whatsoever. Of course he would encourage some of his pupils to take up Thomson and Tait, or Rayleigh's "Sound," or some other classical treatise as an advanced study.[1]

Not only do I think that every teacher in an engineering college ought to have some acquaintance with engineering, but it seems to me equally important to allow a professor of engineering, who ought, above all things, to be a practical engineer, to keep in touch with his profession. A man who is not competing with other engineers in practical work very quickly becomes antiquated in his knowledge: the designing work in his drawing-office is altogether out of date; he lectures about old difficulties which are troubles no longer; his pupils have no enthusiasm in their work because it is merely academic and lifeless; even when he is a man distinguished for important work in the past his students have that kind of disrespect for his teaching which makes it useless to them. If there is fear that too much well-paid professional work will prevent efficiency in teaching, there is no great difficulty in applying a remedy.

One most important fact to be borne in mind is that efficient teachers cannot be obtained at such poor salaries as are now given. An efficient labourer is worthy of his hire; an inefficient labourer is not worthy of any hire, however small. Again, there is a necessity for three times as many teachers as are usually provided in England. The average man is in future to be really educated. This means very much more personal attention, and from thoughtful teachers. Is England prepared to face the problem of technical education in the only way which can lead to success, prepared to pay a proper price for the real article? If not, she must be prepared to see the average man remaining uneducated.

Advocacy of teaching of the kind that was given at Finsbury is often met by the opposition, not only of pure mathematicians and academic teachers, but I am sorry to say also of engineers. The average engineer not merely looks askance at, he is really opposed to the college training of engineers, and I think, on the whole, that he has much justification for his views. University degrees in engineering science are often conferred upon students who follow an academic course, in which they learn little except how to pass examinations. The graduate of to-day, even, does not often possess the three powers to which I have referred. He is not fond of reading, and therefore he has no imagination, and the idea of an engineer without imagination is as absurd as Teufelsdröch's notion of a cast-iron king. He cannot really compute, in spite of all his mathematics, and he is absurdly innocent of the methods of the true student of Nature. This kind of labelled scientific engineer is being manufactured now in bulk because there is a money value attached to a degree. He is not an engineer in any sense of the word, and does not care for engineering, but he sometimes gets employment in technical colleges. He is said to teach when he is really only impressing upon deluded pupils the importance of formulæ and that whatever is printed in books must be true. The real young engineer, caught in this eddy, will no doubt find his way out of it, for the healthy experience of the workshop will bring back his common-sense. For the average pupil of such graduates there is no help. If he enters works, he knows but little more than if he had gone direct from school. He is still without the three qualifications which are absolutely necessary for a young engineer. He is fairly certain to be a nuisance in the works and to try another profession at the end of his pupilage. But if it is his father's business he can make

[1] It is really ludicrous to see how all preachers on technical education are supposed by non-thinking people to hold the same doctrine. The people asking for reform in education differ from one another more than Erasmus and Luther, and John of Leyden and Knipperdoling.

[2] At the most important colleges the usual professor or tutor is often ignorant of all subjects except his own, and he generally seems rather proud of this; but surely in such a case a man cannot be said to know even his own subject.

[1] One sometimes finds a good mathematician brought up on academic lines taking to engineering problems. But he is usually *stale* and unwilling to go thoroughly into these practical matters, and what he publishes is particularly harmful, because it has such an honest appearance. When we do get, once in forty years, a mathematician (Osborne Reynolds or Dr. Hopkinson) who has common-sense notions about engineering things, or a fairly good engineer (Rankine or James Thomson) who has a common-sense command of mathematics, we have men who receive the greatest admiration from the engineering profession, and yet it seems to me that quite half of all the students leaving our technical colleges ought to be able to exercise these combined powers if mathematics were sensibly taught in school and college. We certainly have had enough of good mathematicians meddling with engineering theory and of engineers with no mathematics wasting their time in trying to add to our knowledge.

a show of knowing something about it, and he is usually called an engineer.

Standardisation in an industry usually means easier and cheaper and better manufacture, and a certain amount of it must be good even in engineering, but when we see a great deal of it we know that in that industry the true engineer is disliked. I consider that in the scholastic industry there has been far too much standardisation. Gymnasien and polytechnic systems are standardised in Germany, and there is a tendency to import them into England; but in my opinion we are very far indeed from knowing any system which deserves to be standardised, and the worst we can copy is what we find now in Germany and Switzerland. What we must strive for is the discovery of a British system suiting the British boy and man. The English boy may be called stupid so often that he actually believes himself to be stupid; but of one thing we may be sure, he will find in some way or other an escape from the stupefying kind of school work to which the German boy submits. And if it were possible to make the average English boy of nineteen pass such a silly school-leaving examination as the German boy,[1] and to pass through a polytechnic, I am quite sure that there would be little employment among common-sense English engineers for such a manufactured article. But is it possible that British boys could be manufactured into such obedient academic machines, without initiative or invention or individuality, by teachers who are none of them engineers? No, we must have a British system of education. We cannot go on much longer as we have done in the past without engineering education, and, furthermore, it must be such as to commend itself to employers. Of my Finsbury students I think I may say that not one failed to get into works on a two or three years' engagement, receiving some very small wage from the beginning, and without paying a premium. To obtain such employment was obviously one test of fitness to be an engineer, because experienced men thought it impossible. One test of the system was the greater ease with which new men obtained employment in shops which had already taken some of our students. It is certainly very difficult to convince an employer that a college man will not be a nuisance in the shops. In Germany and France, and to a less extent in America, there is among employers a belief in the value of technical education. In England there is still complete unbelief. I have known the subscribers of money to a large technical college in England (the members of its governing board) to laugh, all of them, at the idea that the college could be of any possible benefit to the industries of the town. They subscribed because just then there was a craze for technical education due to a recent panic. They were ignorant masters of works (sons of men who had created the works), ignorant administrators of the college affairs and ignorant critics of their mismanaged college. I feel sure that if the true meaning of technical education were understood, it would commend itself to Englishmen. Technical education is an education in the scientific and artistic principles which govern the ordinary operations in any industry. It is neither a science nor an art, nor the teaching of a handicraft. It is that without which a master is an unskilled master; a foreman an unskilled foreman; a workman an unskilled workman; and a clerk or farmer an unskilled clerk or farmer. The cry for technical education is simply a protest against the existence of unskilled labour of all kinds.[2]

To have any good general system the employers must co-operate. Much of the training is workshop practice, and it cannot be too often said that this is not to be given in any college. The workshop in a college serves a quite different purpose. Now how may the practice best be given? I must say that I like the Finsbury plan very much indeed, but there are others. When I attended this college in winter I was allowed to work in the Lagan Foundry in summer. In Japan the advanced students did the same thing; they had their winter courses at the college, and the summer was spent in the large Government workshops; the system worked very well indeed.[1] In Germany recently the great unions of manufacturers made facilities for giving a year of real factory work to the polytechnic students, but it seems to me that these men are much too old for entrance to works, and, besides, a year is too short a time if the finished product is to call itself a real engineer. Possibly the British solution may be quite different from any of these. A boy may enter works at fourteen on leaving a primary school or not later than sixteen on leaving a secondary school. In either case he must have the three powers to which I have already referred so often. It will be recognised as the duty of the owners of works to provide, either in one large works or near several works, in a well-equipped school following the Finsbury principle, all the training in the principles underlying the trade or profession which is necessary for the engineer.

No right-thinking engineer has been scared by the newspaper writers who tell us of our loss of supremacy in manufacture, but I think that every engineer sees the necessity for reform in many of our ways, and especially in this of education. People talk of the good done to our workmen's ideas by the strike of two years ago; it is to be hoped that the employers' ideas were also expanded by their having been forced to travel and to see that their shops were quite out of date.[2] In fact, we have all got to see that there is far too much unskilled labour among workmen and foremen and managers, and especially among owners. There may be some kinds of manufacture so standardised that everything goes like a wound-up clock and no thought is needed anywhere; but certainly it is not in any branch of engineering. Many engineering things may be standardised, but not the engineer himself. Millions of money may build up trusts, but they will be wasted if the unskilled labour of mere clerks is expected to take the place of the thoughtful skilled labour of owners and managers. I go further, and say that no perfection in labour-saving tools will enable you to do without the skilled, educated, thoughtful, honest, faithful workman with brains. I laugh at the idea that any country has better workmen than ours, and I consider education of our workmen[3] to be the corner-stone of prosperity in all engineering manufacture. It is from the workman in countless ways that all hints leading to great inventions come. New countries like America and Germany have their chance just now; they are starting, without having to "scrap" any old machinery or old ideas, with the latest machinery and the latest ideas. For them also the time will come when their machines will be getting out-of-date and the cost of "scrapping" will loom large in their eyes. In the meantime they have taught us lessons, and this greatest of all lessons—that unless we look ahead with much judgment, unless we take reasonable precautions, unless we pay some regard to the fact that the cleverest people in several nations are hungry for our trade and jealous of our supremacy, we may for a time lose a little of that supremacy. In the last

[1] The following is, I understand, a stock question at certain gymnasien: "Write out all the trigonometrical formulæ you know." I asked my young informant, "Well, how many did you write?" "Sixty-two," was the answer. This young man informed me that a boy could not pass this examination unless he knew "*all* algebra and *all* trigonometry and *all* science." Strassburg geese used to be fed in France; now they are fed in Germany. German education seems to be like smothering a fire with too much fuel or wet slack which has the appearance of fuel.

[2] I have pointed out how natural it is that business men should feel somewhat antagonistic to college training. Poorly paid, unpractical teachers, with no ideas of their own, have in the past taught in the very stupidest way. They have called themselves "scientific" and "theoretical" till these words stink in the nostrils of an engineer. When I was an apprentice, and no doubt it is much the same now, if an apprentice was a poor workman with his hands he often took to some kind of study which he called the science of his trade. And in this way a pawkiness for science got to be the sign of a bad workman. But if workmen were so taught at school that they all really knew a little physical science, it would no longer be laughed at. When a civil or electrical engineer is unsuccessful because he has no business habits, he takes to calculation and the reading of so-called scientific books, because it is very easy to get up a reputation for science. The man is a bad engineer in spite of his science, but people get to think that he is an unpractical man because of his scientific knowledge. I do believe that the unbelief in technical education so very general has this kind of illogical foundation. Four hundred years ago, if a layman could read or write he was probably a useless person who, because he could not do well otherwise, took to learning. What a man learnt was clumsily learnt; usually he learnt little with great labour and made no use of it; therefore reading and writing seemed useless. Now that everybody is compelled to read and write, it is not a usual thing to say that it hurts a man to have these powers.

[1] It was the idea of Principal Henry Dyer.

[2] Not only is there an enormous improvement in the use of limit gauges and checking and tools, and the careful calculation of rates of doing work by various tools and general shop arrangement, but attention is being paid to the comfort of workmen. There are basins and towels, and hot and cold water for them to wash in. In the old days it would have been called faddy philanthropy. Now, owners of works who scorn all softness of heart provide perfect water-closets for their men; their workshops are kept at a uniform temperature; the evil effect of a bad draught in producing colds, or a bad light in hurting the eyes, is carefully considered. In some of these works it is actually possible for a workman or a member of his family to get a luxurious hot bath for a penny. Will this really pay? Some clever, hard-headed men of my acquaintance say they already see that it does pay very well indeed.

[3] The old apprenticeship system of training men has broken down, and this is the cause of most of our industrial troubles. An apprenticeship system suited to modern conditions is described fully on pp. 68-88 of "England's Neglect of Science."

twenty-three years I have written a good deal about the harm done to England by the general dislike that there is among all classes for any kind of education. I do not say that this dislike is greater than it used to be in England; I complain that it is about as great. But I have never spoken of the decadence of England. It is only that we have been too confident that those manufactures and that commerce and that skill in engineering, for which Napoleon sneered at us, would remain with us for ever. Many writers have long been pointing out the consequences of neglecting education; prophesying those very losses of trade, that very failure of engineers to keep their houses in order, which now alarms all newspaper writers. Panics are ridiculous, but there is nothing ridiculous in showing that we can take a hint. We have had a very strong hint given us that we cannot for ever go on with absolutely no education in the scientific principles which underlie all engineering. There is another important thing to remember. Should foreigners get the notion that we are decaying, we shall no longer have our industries kept up by an influx of clever Uitlanders, and we are much too much in the habit of forgetting what we owe to foreigners, Fleming and German, Hollander, Huguenot and Hebrew, for the development of our natural resources. Think of how much we sometimes owe to one foreigner like the late Sir William Siemens.

But I am going too far; there is after all not so very much of the foolishness of Ishbosheth among us, and I cannot help but feel hopeful as I think lovingly of what British engineers have done in the past. We who meet here have lived through the pioneering time of mechanical and electrical and various other kinds of engineering. Our days and nights have been delightful because we have had the feeling that we also were helping in the creation of a quite new thing never before known. It may be that our successors will have a better time, will see a more rapid development of some other applications of science. Who knows? In every laboratory of the world men are discovering more and more of Nature's secrets. The laboratory experiment of to-day gives rise to the engineering achievement of to-morrow. But I do say that, however great may be the growth of engineering, there can never be a time in the future history of the world, as there has never before been a time, when men will have more satisfaction in the growth of their profession than engineers have had during the reign of Queen Victoria.

And now I want to call your attention to a new phenomenon. Over and over again has attention been called to the fact that the engineer has created what is called "modern civilisation," has given luxuries of all kinds to the poorest people, has provided engines to do all the slave labour of the world, has given leisure and freedom from drudgery, and chances of refinement and high thought and high emotion to thousands instead of units. But it is doing things more striking still. Probably the most important of all things is that the yoke of superstitions of all kinds on the souls of men should be lifted. The study of natural science is alone able to do this, but education through natural science for the great mass of the people, even for the select few called the distinguished men of the country, has been quite impossible till recently. I say that it is to engineers that the world owes the possibility of this new study becoming general. In our country nearly all discoveries come from below. The leaders of science, the inventors, receive from a thousand obscure sources the germs of their great discoveries and inventions. When every unit of the population is familiar with scientific ideas, our leaders will not only be more numerous, but they will be individually greater. And it is we, and not the schoolmasters, who are familiarising the people with a better knowledge of Nature. When men can hardly take a step without seeing steam-engines and electro-motors and telegraphs and telephones and steamships, with drainage and water works, with railways and electric tramways and motor-cars; when every shop-window is filled with the products of engineering enterprise, it is getting rather difficult for people to have any belief in evil spirits and witchcraft.

All the heart-breaking preaching of enthusiasts in education would produce very little effect upon an old society like that of England if it were not for the engineer. He has produced peace. He is turning the brown desert lands of the earth into green pastures. He is producing that intense competition among nations which compels education. If England has always been the last to begin reform, she has always been the most thorough and steadfast of the nations on any reform when once she has started on it. Education, pedagogy, is a progressive science; and who am I that I should say that the system of education advocated by me is that which will be found best for England? In the school education of the average boy or man England has as yet had practically no experience, for she has given no real thought to it. Yet when she does, I feel that although the Finsbury scheme for engineers may need great improvement, it contains the germ of that system which must be adopted by a race which has always learnt through trial and error, which has been led less by abstract principles or abstract methods of reasoning than any race known in history.

NOTES.

WE learn from the *Times* that the work at the Ben Nevis Observatory is to be continued for another year without change in its character. The Meteorological Council in London has agreed to continue its grant of 250*l*. to the low-level observatory at Fort William and the grant of 100*l*. to the high-level observatory. The proceeds derived from furnishing newspapers with meteorological reports and from other sources will amount, it is hoped, to about 150*l*., the sum hitherto yielded. The balance of the cost of maintenance, amounting to about 1000*l*., has been readily subscribed by the public. This satisfactory arrangement will enable the staff to prosecute its work without interruption until the Parliamentary Committee inquiry has reported.

REUTER telegrams state that both craters of the Soufrière have been active since September 11, that communication by wireless telegraphy is to be established between Martinique and Guadaloupe, and that a shock of earthquake was felt in many of the northern towns of South Australia on Friday morning last. A severe shock was also experienced in Adelaide in the evening of the same day.

THE medals and prizes will be distributed to the students of the Royal College of Science, South Kensington, in the theatre of the Victoria and Albert Museum at 2.30 p.m. on Thursday next. The opening address of the new session will be delivered by Prof. John Perry, F.R.S., and Sir Arthur Rücker, F.R.S., will also speak.

THE death is announced in the *Athenaeum* of Theodor v. Heldreich, director of the Botanic Gardens at Athens. The deceased botanist, who was in his eighty-first year, devoted his attention mainly to the flora of Greece, and was the author of numerous works.

AMONG the deaths of foreign men of science we notice the following:—M. Damour—a member of the Paris Academy of Sciences—at the age of 94, and Prof. O. G. Nordenström, of the Stockholm School of Mines. The former was well known for his chemical analyses of rare minerals, and the latter was an authority on mining and the author of numerous technical memoirs.

THE suggestion that a public subscription should be opened for the purpose of purchasing the house in which Pasteur was born and presenting it to the town of Dôle was brought before the French Association at its recent session.

A SCHEME has been proposed to the Italian Minister of Posts and Telegraphs by Mr. Marconi for the creation of a radio-telegraphic station communicating with the stations established or to be established by the Marconi companies in London and in America. The scheme, which is still under consideration, would, if carried out, cost about 70,000 lire. It was announced at a dinner given in Mr. Marconi's honour that the King of Italy had bestowed the Cross of a Grand Officer of the Italian Order of the Crown upon the inventor.

A PRELIMINARY report on the subject of the wireless telegraphy experiments conducted by a board of naval officers